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BULLETIN.

STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

in cooperation with

County of Sacramento

BULLETIN No. 104-11

MEETING WATER DEMANDS IN SACRAMENTO COUNTY

JUNE 1975

CLAIRE T. DEDRICK
Secretary for Resources
The Resources Agency

EDMUND G. BROWN JR.
Governor
State of California

RONALD B. ROBIE
Director
Department of Water Resources

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BIRD'S-EYE VIEW OF SACRAMENTO COUNTY

Photo is taken from about 71,000 feet looking northeasterly c
Sacramento County on July 8 1969, which covers over 90% of t

FOREWORD

At present, about half of Sacramento County's water supply comes from the ground water basin. Since 1940, extractions have exceeded recharge and have caused a gradual lowering of ground water levels and reduction of ground water in storage. Recognizing the need for information to be used to cope with the potentially detrimental effects of such a water level decline, a cooperative study was undertaken in 1968 to provide Sacramento County with information needed to implement water policy guidelines and to provide the State with information on the ground water resources needed for statewide planning.

This bulletin describes the future population, land use, and water requirements of Sacramento County, projected to the year 2020. Using the projected water requirement data and a mathematical model of the ground water basin, five examples of operational management plans were simulated, ranging from 100 percent ground water pumpage to a maximum possible use of surface water.

The report concludes that although sufficient water is available to meet Sacramento County's future total needs, the location of supplies and needs do not match. Adoption and implementation of a specific plan, to halt the steady decline of ground water levels through cooperative action between the County Board of Supervisors and the local water purveyors, is recommended.

This bulletin, together with the previously-published Bulletin No. 118-3 which reported on the geologic and hydrologic phases of this investigation, completes a five-year investigation. Data supporting the findings in this bulletin are available in the files of Sacramento County Division of Water Resources.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
The Resources Agency
State of California

TABLE OF CONTENTS

Table of Contents (Continued)

TABLES

FIGURES

Figures (Continued)

STATE OF CALIFORNIA
Edmund G. Brown Jr., Governor

THE RESOURCES AGENCY
Claire T. Dedrick, Secretary for Resources

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ACKNOWLEDGMENT

The Department of Water Resources acknowledges the information and advice provided by the Ground Water Advisory Committee during the preparation of this bulletin. This committee, which was consulted on significant items in the investigation, was established to give guidance to the investigators. Its members are from the following organizations:

Arcade County Water District
Arvin Water Company
Carmichael Irrigation District
Citizens Utilities Company of California
Citrus Heights Irrigation District
City of Sacramento
Del Paso Manor County Water District
Fair Oaks Irrigation District
Florin County Water District
Fruitridge Vista Water Company
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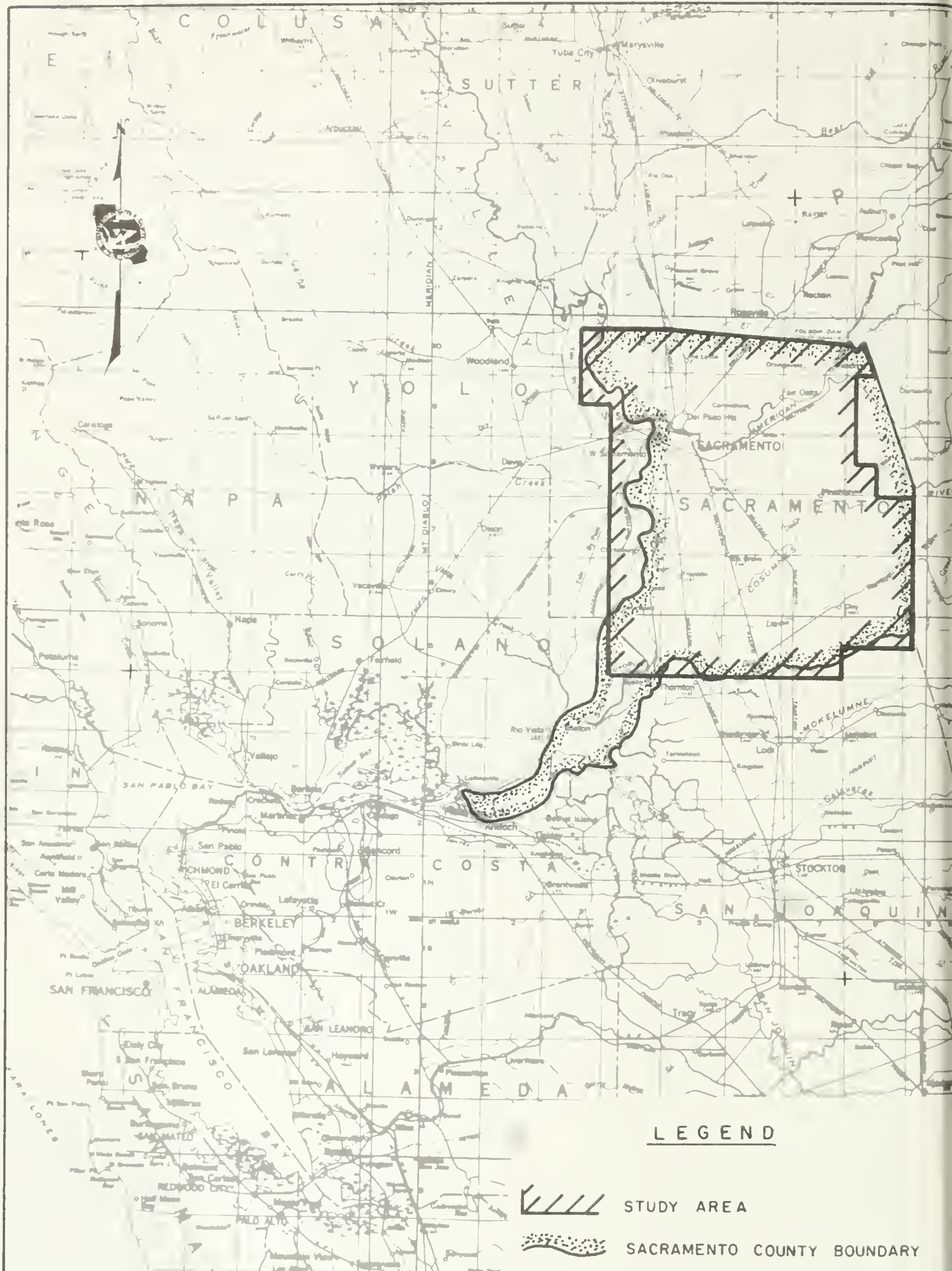


Figure 1. AREA OF INVESTIGATION

CHAPTER I. INTRODUCTION, CONCLUSIONS, AND RECOMMENDATIONS

The combination of (1) the average annual amount of water flowing in streams in and adjacent to Sacramento County and (2) the average annual pumpage of water from the water-bearing materials in the County is greater than the average annual water requirement of Sacramento County. The large amounts of water that flow through the County during the spring and winter months cannot be utilized without providing adequate storage to make it available in the summer and fall. However, to provide this storage, an application to appropriate water must be filed and the water must be put to beneficial use. Some water agencies have filed to appropriate amounts of surface water that are in excess of their future demands, while other agencies have no entitlement to surface water and rely entirely on ground water.

Historically, surface water has not been utilized to its fullest extent in Sacramento County. This is in part due to the size and cost of features such as dams and pipelines which would be required to make winter and spring flows available at the proper time and location.

In contrast to the lack of full development of surface water, the development of local ground water resources has continued at a rapid pace. Over the years, pumpage from the ground water basin gradually has exceeded its recharge capability, which in turn has caused a long, slow decline in water levels. This continuing decline of water levels, and the dependence of the County on ground water, prompted the California Department of Water Resources and Sacramento County to enter into a cooperative agreement to formulate alternative plans for the integrated use of surface and ground water supplies. The long range goal of this action is to protect a major ground water basin of the State against the adverse effects of over-development and to provide the people of Sacramento County with the information required to assure an adequate future water supply.

Objective of Investigation

The objective of the current investigation is to (1) provide local agencies in Sacramento County with information on a wide range of alternative plans for the management of the ground water basin in coordination with surface water supplies and facilities, and (2) suggest the type of plan which would continue the full utility of the ground water resource. With the information provided in this bulletin, the County Board of Supervisors and managers of the various local agencies will be in a position to make an informed selection of the most suitable plan.

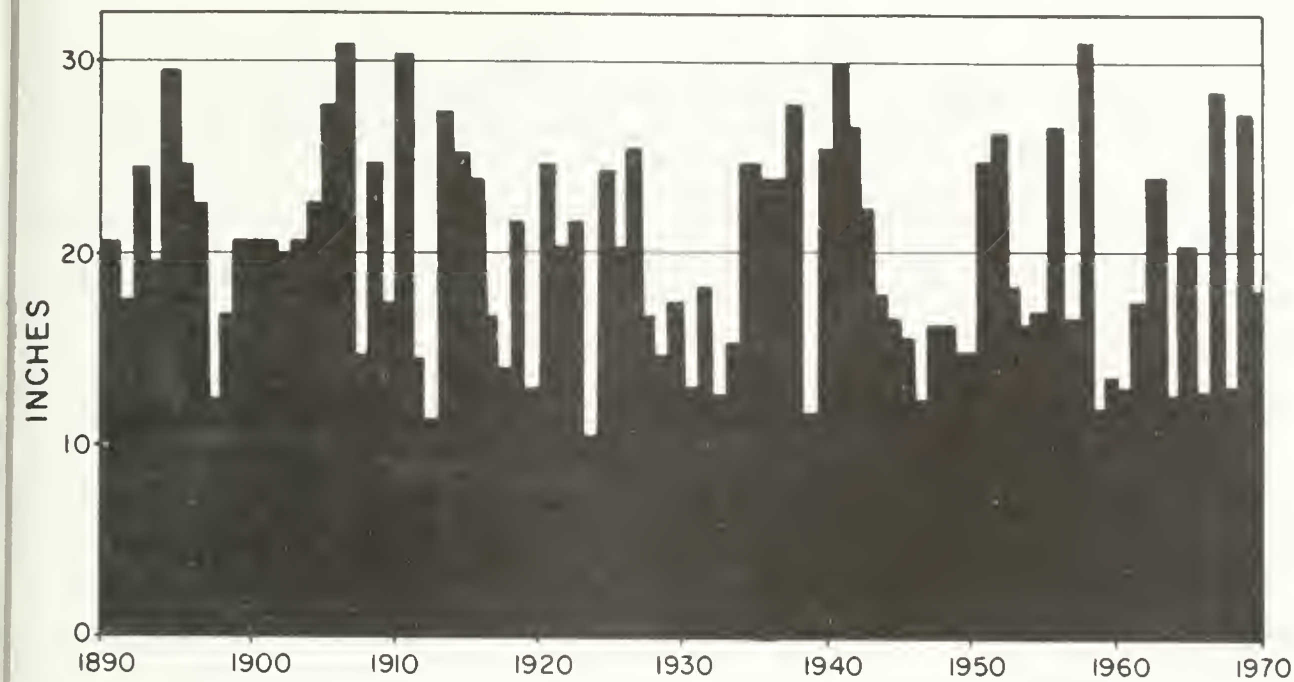
The need for such comprehensive planning arises from the increasing demand for water, the increasing cost of obtaining it, and the need for local water purveyors to make decisions on firming up present surface water sources and to complete contractual agreements for water needed for the future.

Area of Investigation

Sacramento County, shown on Figure 1, is located in the north-central part of the Great Valley. It is bounded by Sutter and Placer Counties on the north, El Dorado and Amador Counties on the east, San Joaquin and Contra Costa Counties on the south, and Yolo and Solano Counties on the west. The approximate total area of the County is 644,000 acres. Of this area, 528,000 acres are valley lands (6 percent or less slope), 100,000 acres are hill lands (between 6 and 20 percent slope), and 16,000 acres are mountainous (greater than 20 percent slope). For the purposes of the present investigation, an area representative of the basic ground water body was used. The boundary of this ground water body is at the contact with the nonwater-bearing rocks on the east and along a line across which subsurface flow is at a minimum for the other three sides. Both the Sacramento County boundary and the study area boundary are shown on Figure 1.

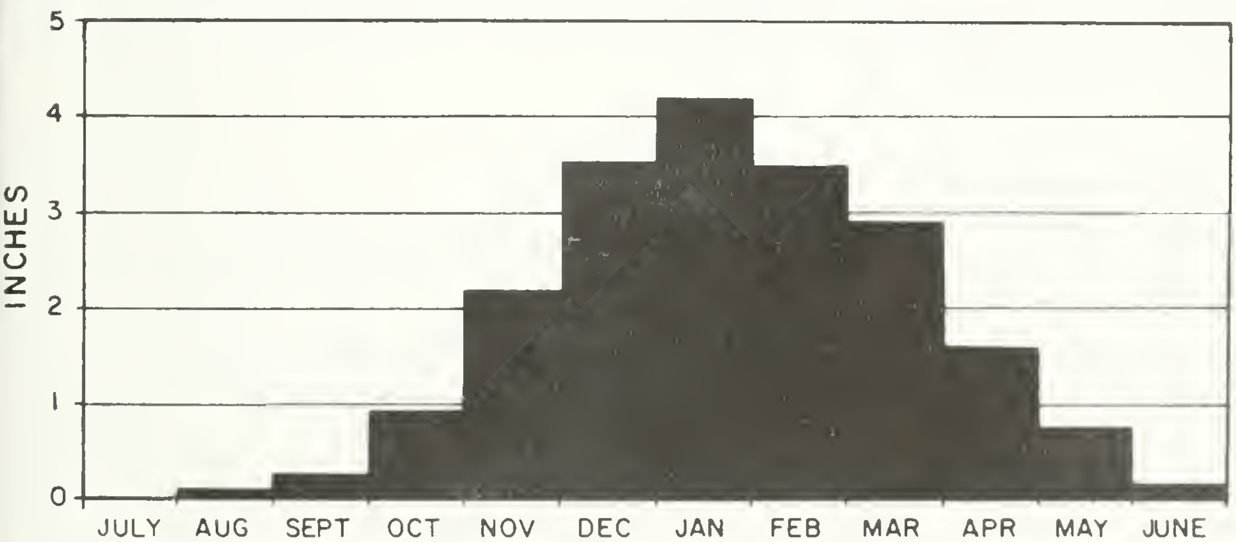
The climate of Sacramento County is characterized by warm, dry summer days and pleasant nights, with nearly cloudless skies. Winters are mild, with relatively light rainfall. On the average, Sacramento County enjoys 308 rainless days per year, based on records from July 1877 to June 1970. The average annual precipitation for Sacramento County is 19.91 inches, based on the 1891 to 1970 average of the combined annual precipitation records for Represa (Folsom Prison), Galt, and Sacramento Weather Bureau City gages. During this period a maximum annual precipitation of 31.06 inches occurred in 1957-58 and a minimum annual precipitation of 10.35 inches in 1923-24. Variations in the average annual and monthly amounts of precipitation are shown on Figure 2.

Sacramento County has many areas which are highly developed to a variety of urban and agricultural uses. Development of the County goes back over 100 years, to the early 1840's. Following the gold rush of 1849, agriculture became the prime activity for many decades. Water development in the County dates back to 1854, with the diversion of water from the Sacramento River for municipal purposes by the City of Sacramento. During this time upstream river water also was being diverted for hydraulic mining purposes. As this latter use of water diminished, it was replaced by agricultural water use in the 1880's. The pumping of ground water for agricultural purposes began in the 1890's and has increased significantly since then because of continuing advances in design and construction techniques of high-capacity water wells.



YEAR (JULY - JUNE)
AVERAGE ANNUAL PRECIPITATION
1890-91 to 1969-70

(Average of combined annual precipitation for Repressa, Galt, and Sacramento WB City gages.)



AVERAGE MONTHLY PRECIPITATION

Figure 2 AVERAGE ANNUAL AND MONTHLY PRECIPITATION

It has been estimated that by 1928, about 30 percent of the total agricultural acreage in the County was irrigated by ground water. This percentage remained fairly constant during the next ten years; it began to increase significantly during the 1940's. Increased use of ground water for urban purposes began during the 1950's, and by 1970, the total annual municipal and industrial water use in Sacramento County was 300,700 acre-feet. Of this amount, nearly 190,000 acre-feet was ground water.

Sacramento County lies entirely within the Sacramento River watershed. Runoff from the Sierra Nevada enters the County by way of a number of tributaries to the Sacramento River; the principal tributaries are: the American River, Cosumnes River, Dry Creek, and Deer Creek. Sacramento River forms the western boundary of the County and all surface water outflow from the County goes by way of this river, which empties into the San Francisco Bay system.

Conduct of Investigation

The work program for this investigation was divided into three phases: geology, hydrology, and operation-economics. The first two phases of this study have been reported in Bulletin 118-3, "Evaluation of Ground Water Resources, Sacramento County", 1974. The geology and hydrology phases developed information on the local water supplies, analyzed and evaluated geologic and hydrologic data, and developed a mathematical model of the ground water basin which simulated changes in water levels in response to specific surface and ground water use. The operation-economic phase of the investigation, reported on in this bulletin, includes proposed alternative operational plans, their estimated costs, and the physical effects of their operation as determined by use of the mathematical model.

Geology and Hydrology Phases

Bulletin 118-3 contains a detailed report on the geologic and hydrologic phases of the current investigation. A brief summary of these two phases is presented below.

Sacramento County is situated in the southern part of the Sacramento Valley and adjacent portions of the Sierra Nevada. That portion of the County in the Sacramento Valley is underlain by a sequence of water-bearing materials that has a westerly dip ranging from 5 to 300 feet per mile and approaches several thousand feet in thickness under the Sacramento River. To the east of the water-bearing materials are nonwater-bearing rocks, which crop out in the northeastern part of the County. Much of the water-bearing materials underlying the County range in composition from cemented gravels containing zones of hardpan, to older alluvial materials containing layers of hardpan, claypan, fine sand, and silt. Along major waterways, unconsolidated stream channel deposits are the rule. The southwestern part of the County is underlain by a thick sequence of organic materials; peat and related deposits are common.

The subsurface geologic features of Sacramento County were identified and delineated by a computer-assisted technique using information contained on logs of water wells. This technique, called the GEOLOG program, allowed for the rapid identification and delineation of the many subsurface channels that make up the alluvial fill in the Sacramento Valley. A typical representation of these various buried channel deposits is presented in Figure 3. This figure shows the channel network in the upper zone to a depth of 200 to 350 feet. A lower network of channels also was identified. A detailed discussion of these two channel networks appears in Bulletin 118-3. Geologic information developed during the study for Bulletin 118-3 also was used to determine the ground water storage capacity and transmissivity of the various water-bearing materials; these values were used as input to the ground water model.

In the hydrologic phase of the study, the primary goal was to determine the ability of the ground water basin to accept, store, and move water. The evaluation of this ability was made by determining the amount of water being pumped from the ground water basin, flowing into the County from adjacent counties, and entering the ground water basin from precipitation, irrigation, and stream infiltration. The total quantity of water involved was estimated over a study period from 1962 through 1968. This period was selected as the best period to represent the average climatic conditions and current development. The result of this inventory of recharge to and withdrawals from the ground water basin is shown in Table 1.

Table 1

GROUND WATER INVENTORY STUDY AREA
(In Thousand Acre-Feet)

Water Year	Recharge from: Irrigated Agricultural Areas	Urban Areas	Native Areas	Stream	Sub-Surface Inflow	Pumpage	Net Recharge	Change in Storage
1962	161.4	17.4	112.0	119.9	3.6	417.2	- 2.9	- 19.7
1963	137.4	14.9	94.4	109.7	3.5	317.6	42.3	51.5
1964	93.0	8.0	48.0	105.2	4.1	422.2	-163.9	-171.0
1965	121.8	14.1	121.3	158.7	5.4	385.6	35.6	29.6
1966	98.8	4.7	61.6	95.1	6.0	449.4	-183.2	-196.2
1967	160.1	48.7	220.0	172.1	5.9	337.5	269.3	303.4
1968	80.0	4.9	60.2	89.7	4.5	397.1	-157.8	-157.7
Average	121.8	16.1	102.5	121.5	4.7	389.5	- 22.9	- 22.9

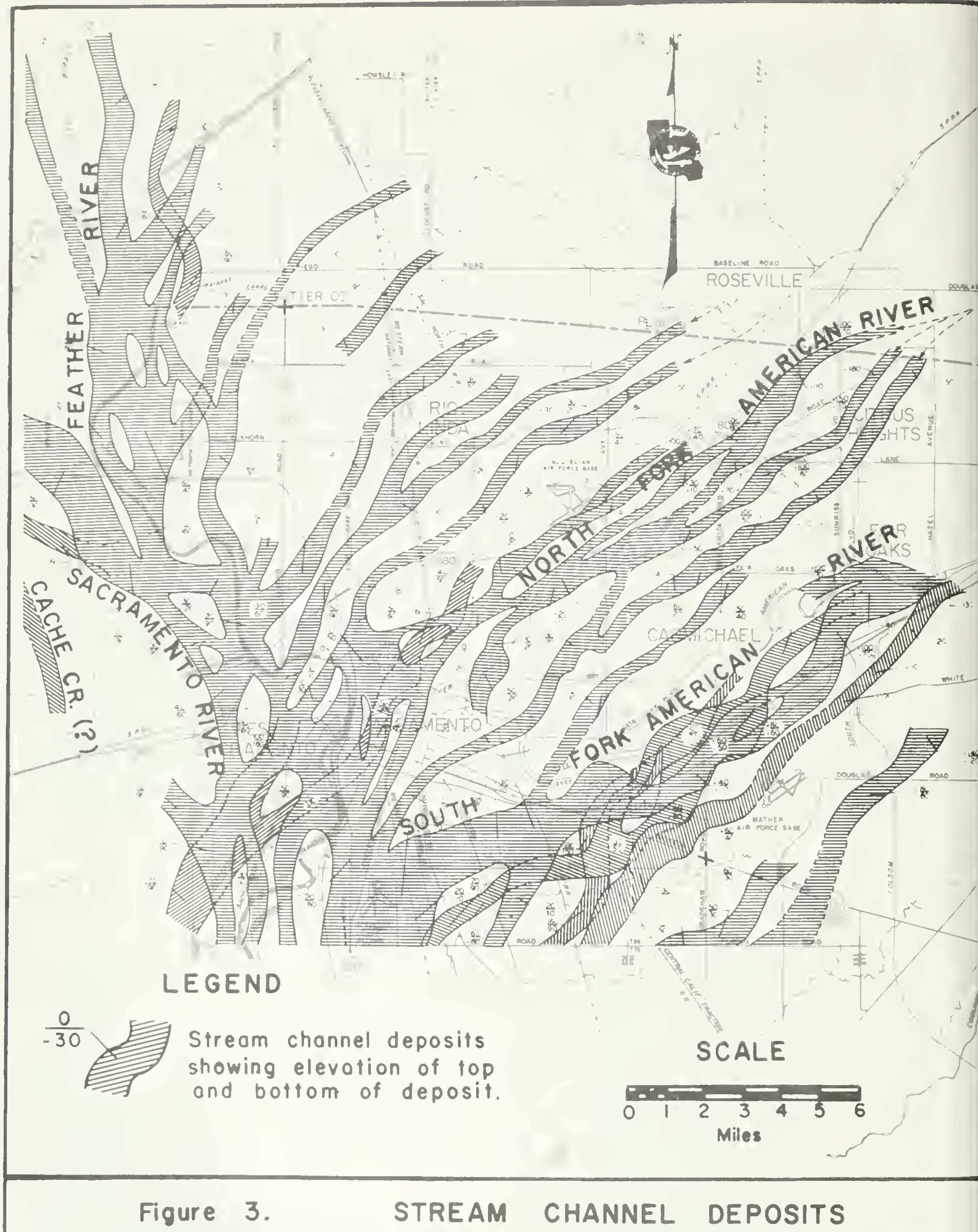


Figure 3. STREAM CHANNEL DEPOSITS
Sheet 1 of 2

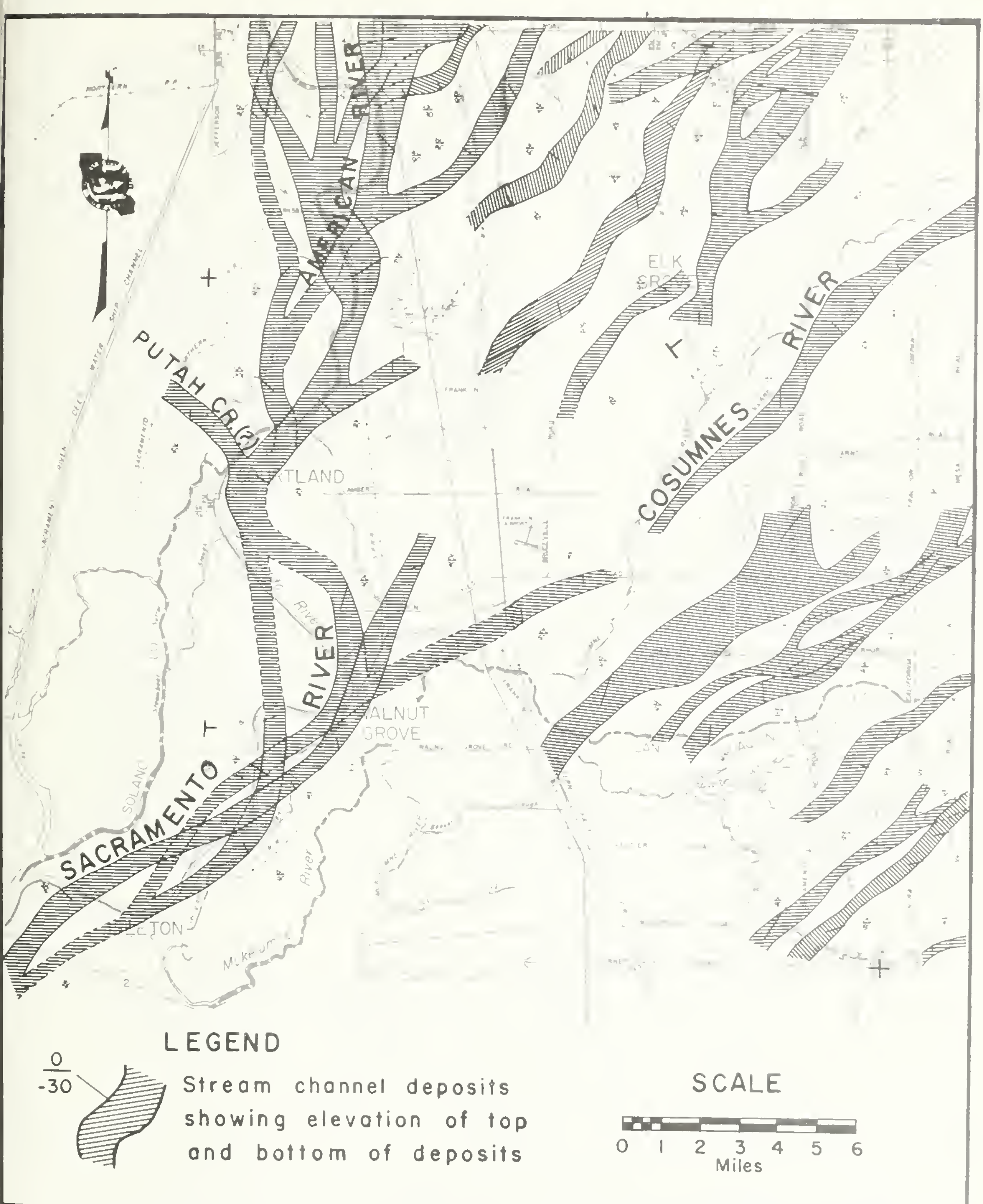


Figure 3. STREAM CHANNEL DEPOSITS
Sheet 2 of 2

To verify the accuracy of the hydrologic inventory, the annual change in the amount of ground water in storage was computed from historic water levels and compared with the annual amount of net recharge in the inventory. The comparison listed in Table 1 shows that although there are some differences on an annual basis, the average annual amounts are equal.

To be able to evaluate alternative plans in detail, it was necessary to subdivide the ground water basin into a number of small parts, or nodes, and then describe the relationship between the adjacent nodes. A mathematical model of the ground water basin was developed for this purpose and consisted of 102 nodes oriented as shown in Figure 4. Each of the nodes represented an area of like characteristics, and the relationships between adjacent nodes were described by linear equations. All linear equations were solved simultaneously on a digital computer.

Data on the net recharge for each node are used as input to the mathematical model. The output of the model is the theoretical water level for each node. The model is verified by adjusting input and internal equation values until there is an acceptable agreement between computed and historic water levels for the study period.

The verified model has an average error of closure or deviation from the historical record of 0.56 feet. Larger errors were produced in foothill nodes where historic water levels were incomplete or ill-defined. Because the foothill nodes have only a thin cover of alluvium, and consequently have only small ground water storage capacities, large errors in these nodes do not affect the overall accuracy of the model. The verified model is of sufficient accuracy to be used as a workable management tool for the study of the response of the ground water basin to any operational plan that may be imposed upon it.

Operation-Economics Phase

Because this investigation deals with future water service in the study area, a number of factors affecting the supply and cost could not be predicted conclusively. Among these factors were future water demands and land use, future mean water supply, and the future pricing policies of the Bureau of Reclamation. Thus, the conditions that might develop in the future have had to be estimated. During the present investigation, certain of these estimated conditions changed, and they are expected to continue to change in the future. To determine the effects of these changing conditions on the economic findings of the study, an evaluation was made of the impact of these changes occurring during the study. This impact was not found to be large enough to change any conclusions that would be arrived at by evaluating the results presented.

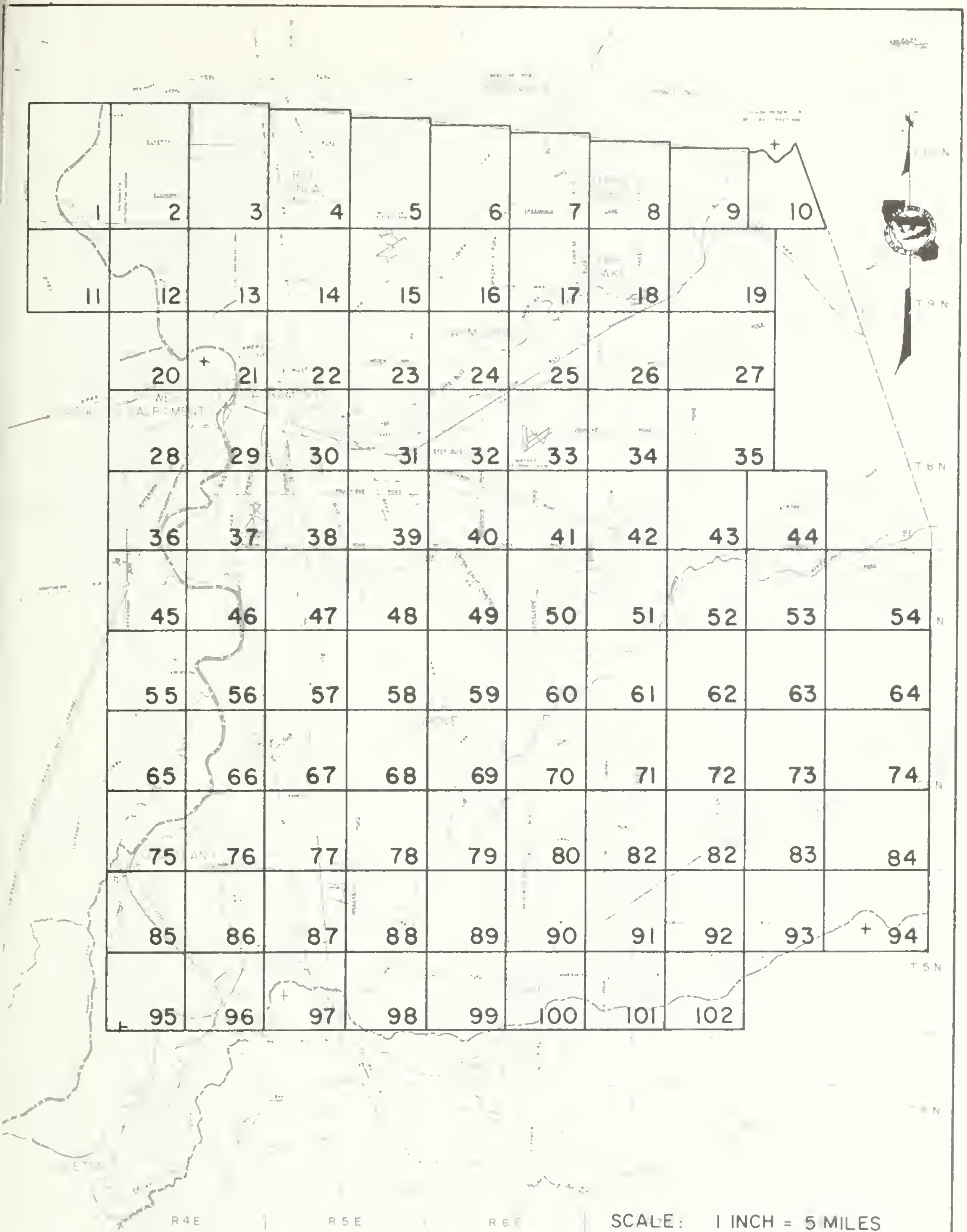


Figure 4. NODAL PATTERN,

SACRAMENTO COUNTY GROUND WATER STUDY

The total costs of alternative plans are very sensitive to any changes in the costs of surface water and power for pumping ground water. Escalation of construction costs would have about the same effect on all of the conjunctive use plans.

A wide range of alternative plans for conjunctive operation of the ground water basin in combination with surface water supplies were considered. The economic impact of a number of operational variables are reported on, as well as legal, political, social, and organizational factors which must also be considered in the selection of a particular plan of operation.

The land use and population projections used in this report are considered to be the most probable; however, significant local, national, and international conditions may cause changes to occur. Shifts in the location of projected urban and agricultural growth within the study area could change some of the water facilities required, or the depth to water on a local basis, but would have little effect on the overall costs of the alternative plans presented. For example, a major change in the projected acreage of rice, the acreage of irrigated agriculture, or the amount of water required for power plant cooling would be more significant and could thus require a reevaluation of the effects and costs of alternative plans.

Conclusions

1. The total amount of water available (existing use and future commitments) to the Sacramento County area is greater than the anticipated water demands to the year 2020, but supplies available to the various water purveyors in the County are not in proportion to these anticipated demands, i.e., the demands in certain areas will exceed supplies, and vice versa.

2. Average annual recharge to the Sacramento County ground water basin during the period 1962 to 1968 is about 370,000 acre-feet. During the same period, pumpage of ground water exceeded recharge by approximately 20,000 acre-feet per year, resulting in an average annual decline of water levels of over one foot. This average rate of decline is continuing.

3. In 1970, the annual water demand was about 840,000 acre-feet, and this amount is expected to increase to about 1.13 million acre-feet by the year 2020. The average annual increase in water demand is estimated at about 6,000 acre-feet. In addition, 75,000 acre-feet of water annually will be required for power plant cooling by 1980.

4. Changing land use will not significantly modify average annual amounts of recharge to the ground water basin

because the recharge from urban and agriculture is about the same.

5. Any plan to stabilize ground water levels must limit pumping to about 20,000 acre-feet less than the present annual pumpage unless an artificial recharge program becomes a part of the plan.

6. Based on the assumption that the average annual pumpage will be about equal to the average annual recharge, the average annual amount of surface water required by the County is less than the total amount available. The average annual amount of surface water required will increase from about 500,000 acre-feet in 1970 to approximately 800,000 acre-feet in 2020.

7. Early water rights filings by the City of Sacramento and others has resulted in large amounts of surface water being available for local use.

8. The full amount of surface waters available to the City of Sacramento will probably not be fully utilized by 2020 even if all parts of its service area are served only by surface water. The three reasons for this are: (1) the incorporated service area is less than that designated in its water rights application; (2) the prohibition of pumping by industries and individuals within the service area may be neither practical nor desirable; and (3) the growth of population has slowed down and is distributed in a manner different than in earlier forecasts.

9. Five alternative plans for the period to 2020, each using different mixtures of surface and ground waters, were tested as examples. The results indicate that a stable ground water basin can be achieved by use of approximately 58 to 60 percent surface water. The results of each example are as follows:

   Example, Plan A, Continuation of present ground to surface water ratio would result in: (1) the use of 1.8 million acre-feet of ground water in storage; (2) an increase in the rate of decline of ground water levels; and (3) the use of about 50 percent ground water.

   Example, Plan B, Maximizing the use of surface water has serious institutional and pricing problems; the ground water basin would be replenished to full capacity by 1995.

   Example, Plan C, Increasing surface water use with minimum additional facilities would result in a 44 percent use of ground water for the period, a one-half million acre-foot decrease of ground water in storage, and a small overall increase in depth to water although some areas would experience up to a 50-foot drop in water levels.

Example, Plan D, Replenishment of the ground water basin by 2020 requires slightly more (5 percent) ground water than Plan B, and would require the solution of some institutional problems, such as limiting pumping and requiring use of surface water by certain districts.

Example, Plan E, Use of no surface water would result in a rate of decline in water levels of approximately 7 feet per year, and many wells in the eastern portions of the County would be dewatered prior to 2020.

10. The use of varying amounts of surface and ground waters to satisfy future demands results in relatively small total cost differences. The exclusive use of ground water would result in a large increase in total cost due primarily to increased power costs of pumping from a declining water surface.

11. A satisfactory method of assigning an economic value for the quality differences between surface and ground water could not be determined because both surface and ground waters are of excellent quality, with the exception of the presence of iron and manganese in ground water.

12. Surface water is more expensive to treat and deliver for municipal use than is ground water. This will remain the case until ground water levels drop about 200 feet, due to increased power costs for the additional lift.

13. At the present time, ground water is the less costly source of water supply for agricultural use. However, if ground water levels drop about 70 feet, surface water and ground water will cost the agricultural user about the same, based on a selling price of $6 per acre-foot.

14. Because Sacramento County has adequate supplies of both surface water and ground water, several alternatives are feasible for supplying present and future demands for water. The choice of a long-range plan must consider the desires of water purveyors along with the basic information provided in this bulletin. The Department stands ready to assist the County under a future cooperative agreement to examine the selected alternatives and to provide additional information needed to select and implement a long-range plan.

15. Long-range plans integrating the use of surface and ground water are essential to the successful management of any ground water basin. Without such plans a time may arrive when pumpage must be reduced to a level equal to the amount of ground water recharge or else adverse effects, such as higher pumping costs and degradation of the ground water supply, could occur. The past operations of the various water purveyors in diverting and serving surface water have prevented a severe decline of ground water levels during the past 30 years.

16. The types of problems to be resolved are for the most part institutional and financial. Whether the solution requires a new overall district, interagency agreements, or some other institutional form, prompt action could utilize the impact of this study as a starting point. Utilization of an advisory committee to represent the interests of both the existing water purveyors and the individual well owners would assist in maintaining public interest in development of a county water plan.

Recommendations

It is recommended that the County Board of Supervisors, in cooperation with the local water purveyors:

1. Adopt conjunctive use of ground and surface water supplies as a management concept.

2. Adopt stabilization of ground water levels as a management concept.

3. Develop a specific schedule for the orderly use of existing and potential water supplies of the County to reverse declining water levels, protect water quality, or provide adequate water service.

4. Develop and adopt a specific plan, based on Example Plans C and D described herein, to implement the movement of additional water supplies to areas of need either by way of surface distribution systems or through the ground water system.

5. Form or modify an organization or agency to oversee the construction of the necessary facilities, equalize payments and benefits, preserve cooperation between the water purveyors of the area, and maintain the water rights of the area.

CHAPTER II. WATER REQUIREMENTS

Sacramento County has experienced a significant urban growth and expansion of its irrigated agriculture. As a result, there has been an extensive development of local water resources. Although future growth is not expected to be as rapid, an increase in water requirements is anticipated and the County must make some decisions regarding the further development of its water resources. Some of the available considerations and options are discussed in subsequent chapters. This chapter discusses the derivation of estimates of future water needs based on historic water use, unit water use, population, land use, and water requirements.

Historic Water Use

Water supplies to meet the various water demands in the study area within Sacramento County consist of locally pumped ground water and local surface water diversions. Most of the surface water is diverted from the Sacramento and American Rivers directly into irrigation works or treatment plants. Figure 5 depicts the 1969 water use for the study area within Sacramento County, showing percentages for combinations of use and source. The total water use for 1969 was about 800,000 acre-feet, of which 550,000 acre-feet was for irrigation and 250,000 acre-feet was municipal and industrial. Ground water supplied 46 percent of the total.

Between 1962 and 1968, about 389,500 acre-feet per year, or 45 percent of the demand for delivered water in the study area (see Figure 1), was met with pumped ground water, and about 476,000 acre-feet, or 55 percent, was met by surface water.

Unit Water Use

The use of water varies with weather, cultural habits, cost, water quality, and availability. The Department of Water Resources has determined statewide unit water uses for various crops on an areal basis and for urban use on a per capita basis.

The requirement for irrigation water for agricultural use varies by crop. The average applied unit water use for various crops ranges from a low of 0.5 acre-feet for safflower and 1.8 acre-feet for sorghum and truck crops to a high of 7.8 acre-feet for rice. A weighted average of 2.74 acre-feet

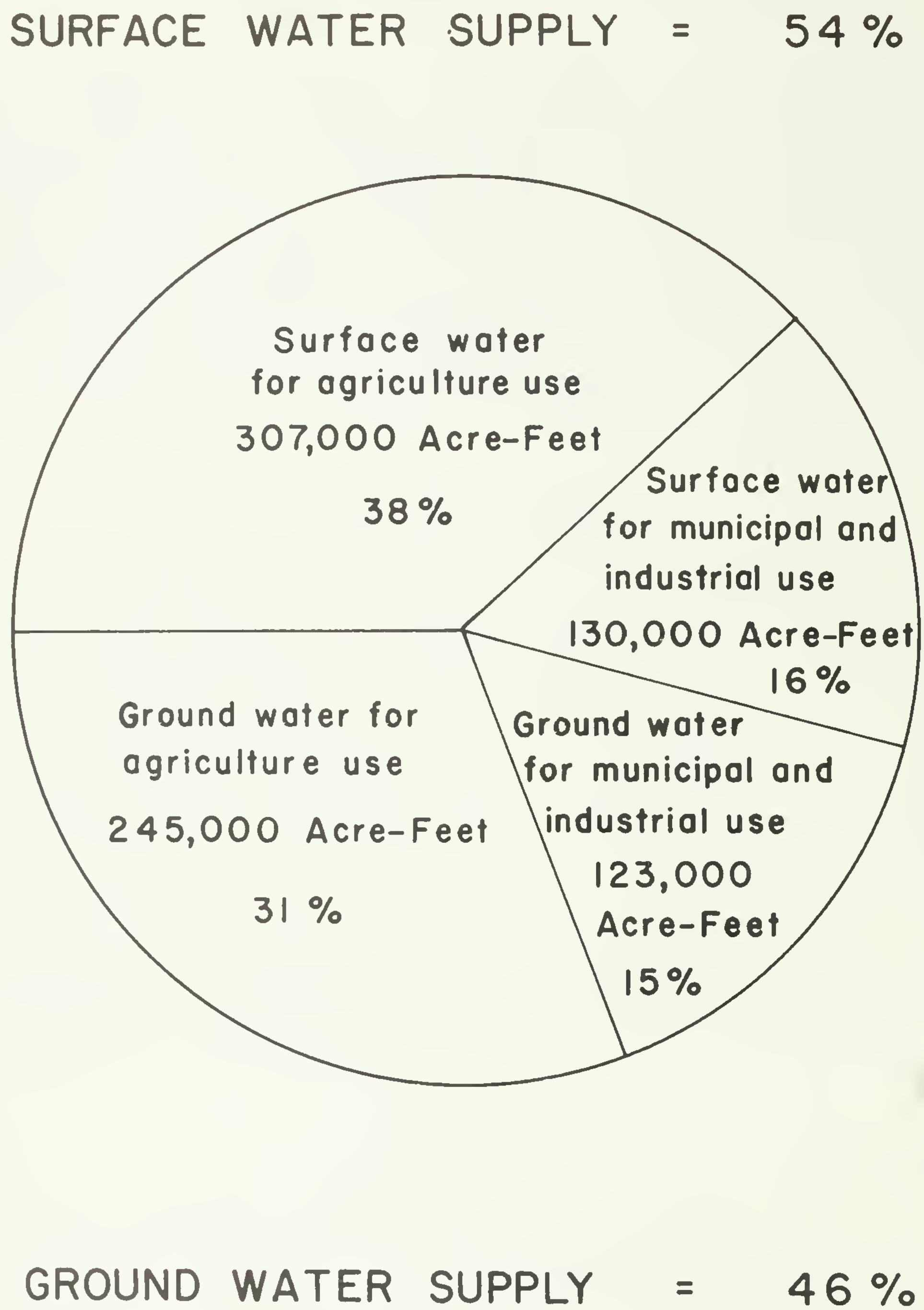


Figure 5. 1969 WATER USE FOR STUDY AREA WITHIN SACRAMENTO COUNTY

was used to calculate agricultural water requirements, for all general irrigated agriculture, with the exception of rice, which was considered separately.

Municipal and industrial water use in the study area averages about 340 gallons per capita per day (GPCD) or roughly 0.38 acre-feet per year (AFY) per person. In urban areas of low density it was found that use exceeded the 0.38 AFY per capita; consequently a higher value was used where it was determined appropriate. This higher value is based on estimates of out-of-house use on estate type lots and approximates 3.3 AFY. Each nodal unit of the mathematical model was checked in an attempt to arrive at a more accurate reflection of future water demands.

Future Population

The water needs of the individual and his immediate surroundings, coupled with the increasing water demand by those facilities that serve him, greatly affect the demand for water. Population, however, has generally been used to calculate changes in urban water demands due to growth. An exception is made in those instances where a change is expected in the historic relationship between population, economic activity, and average density.

Table 2 and Figure 6 summarize the historical and projected population for the United States, California, and Sacramento County. In general, growth rate characteristics have been and are expected to be similar. The slowdown in birth rates of recent years will have a depressing effect in each case as suggested by the flattening of the growth curves beyond 1980.

It has been the policy of the Department of Water Resources to base its projections of population on Department of Finance studies. The latter prepares long-range estimates of population for the State as a whole and by county approximately every two years. The most recent series was published in June 1974, and titled Population Projections for California Counties 1975-2020, Report 74, p-2.

During the conduct of the major work of this study, the latest population projections were those prepared by the Sacramento County Advance Planning Unit (SCAPU), which are similar to those identified as the "Baseline" in the Finance report (1974). Since the differences between SCAPU and Department of Finance D-100 projections are very small and would not affect water demands significantly, the SCAPU values and their extensions were used for County and study area population projections and as a basis for determining future urban water demands.

To place population projections in their proper perspective, the four series of population forecasts prepared by the Department of Finance (1974) are shown on Table 3. The D-100 series is

Table 2

COMPARISON OF POPULATION GROWTHS

Year	United States[1/]		California[2/]			Sacramento County[2/]		
	Pop., Thous.	% Incr.	Pop., Thous.	% of U.S.	% Incr.	Pop., Thous.	% of State	% Incr.
1900	75,995		1,485	1.95		46	3.10	
1910	91,972	21.0	2,378	2.59	60.1	68	2.86	47.8
1920	105,710	14.9	3,427	3.24	44.1	91	2.66	33.8
1930	122,775	15.8	5,677	4.62	64.4	142	2.50	56.0
1940	131,669	7.2	6,907	5.25	21.7	170	2.46	20.0
1950	150,697	14.5	10,586	7.02	53.2	277	2.62	62.7
1960	178,464	18.4	15,863	8.89	49.8	503	3.17	81.6
1970	203,805	13.2	20,009	9.82	26.1	631	3.15	20.3

1/ Statistical Abstract of the United States, 1970
2/ California Statistical Abstract, 1970

Table 3

COMPARISON OF POPULATION PROJECTIONS
(in 1,000)

Year	Sacramento County					Study Area[3/]
	C-150[1/]	D-150[1/]	D-100[1/]	E-0[1/]	SCAPU[2/]	
1970					631	660
1975	697	696	696	693		
1980	763	757	754	736	760	800
1990	924	902	885	817	882	937
2000	1,076	1,032	996	877	1,004	1,073
2010	1,264	1,182	1,122	937		
2020	1,488	1,353	1,266	1,001		1,277

1/ Report 74 P-2, Department of Finance, June 1974
2/ Sacramento County Advance Planning Unit
3/ Based on SCAPU projections

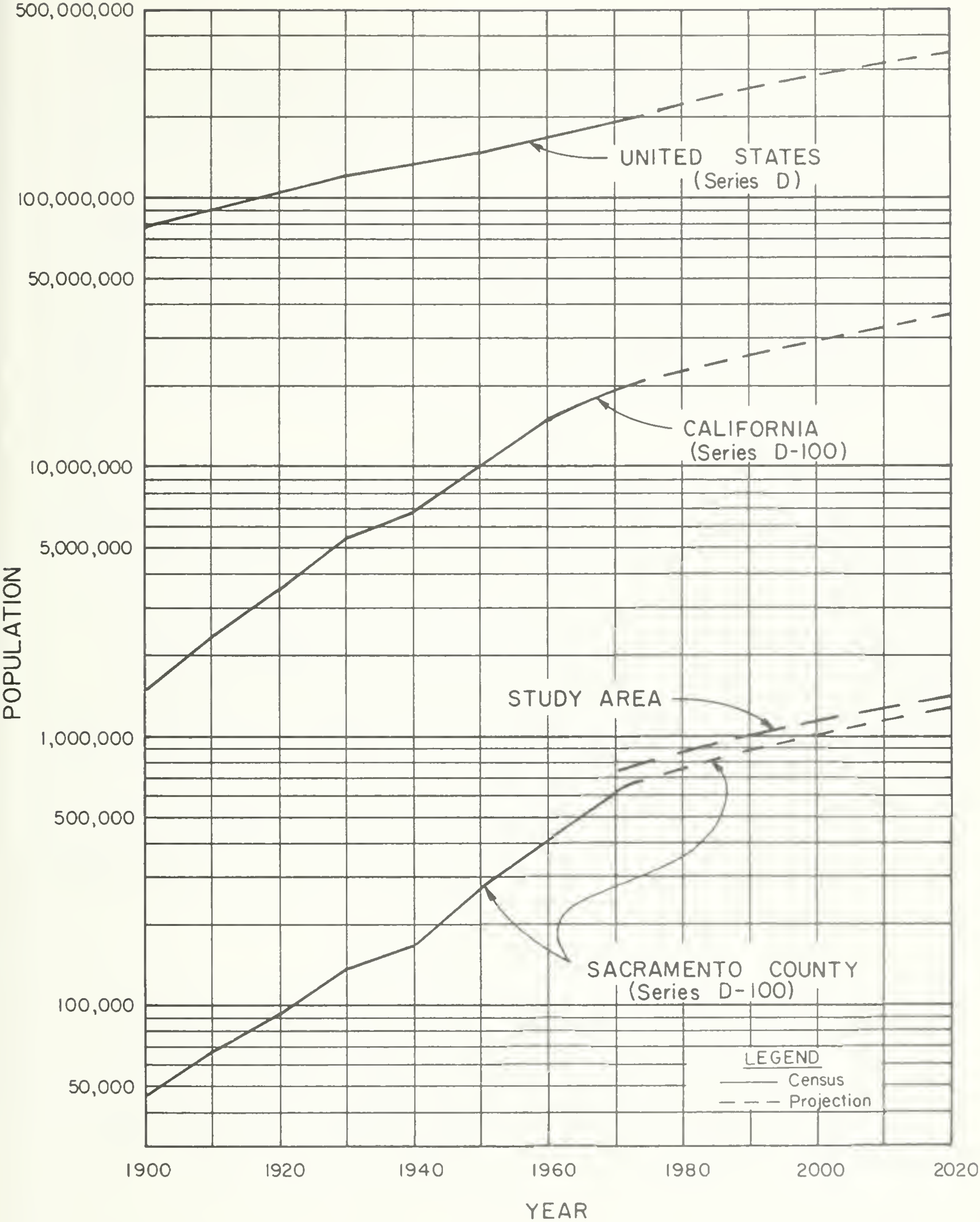


FIGURE 6. COMPARATIVE POPULATION PROJECTIONS

believed to have the greatest probability of occurring, and is used for current planning purposes throughout the State. Also shown in Table 3 are the projections by the Sacramento County Advanced Planning Unit which were used for the County and the study area projections. Both of these latter projections are based on the Department of Finance projections (September 1971).

For the purposes of this study, the projected population was disaggregated by the Sacramento County Advanced Planning Unit into 19 growth rate units called statistical areas (Figure 7). The 1980, 1990, and 2000 projected population and holding capacities for each of the units are listed in Table 4.

The population projections were also disaggregated to the nodal units of the mathematical model.

Future Land Use

Changes in land use result from urbanization (population change) and the addition or deletion of cultivated lands and open space. They are also related to agricultural product demand, and limited by the crop potential of native lands and the availability of water.

The land use projections for this study were obtained from the Coordinated Statewide Planning Unit of the Department of Water Resources. These projections were made for Bulletin 160-70, "Water for California, The California Water Plan Outlook in 1970". Information to be contained in Bulletin No. 160-74 was not available in time for use in this bulletin. If major changes in projected land use occur, they can be readily evaluated by use of the mathematical model of the study area.

The projection for Sacramento County covered two hydrologic study areas (Figure 8), namely the Sacramento Basin and the Delta-Central Sierra. These two hydrologic study areas are divided into twelve subareas within Sacramento County. Projected land use to the year 2020 is shown in Table 5 and on Figure 9.

Future Water Requirement

The procedure used to estimate the future water requirement is shown on Figure 10 as a flow diagram for a computer program written to compute the total water requirement. Irrigated agriculture and rice acres, population, and urban acres were projected for each node to the year 2020. Applied unit water uses for irrigated general agriculture and rice were estimated to be equal to (a depth of) 2.74 acre-feet per acre and 7.80 acre-feet per acre, respectively. General agriculture and rice acres were not lumped together for projection purposes because the unit water use for rice is about three times greater than that for general agriculture. Agricultural water demand for each node is determined by summing the products of the projected agriculture and rice acres by their respective unit applied water requirements.

Municipal and industrial water demand for each node was determined by either the population times the unit use value, or urban acres times the minimum urban unit use amount, whichever was greater.

The present water use and future water requirement for the study area and County are summarized in Table 6. As noted previously on population projections, the projected water requirements are a best estimate of future requirements. The urban water requirement can vary with changes in population growth rates, and the requirement for irrigation water can be affected by domestic policies and the international food supply.

Non-Consumptive Requirements

In 1962 the concept of an American River Parkway was adopted by the Sacramento County Board of Supervisors and made a part of the recreation element of the Sacramento County General Plan. This development has received state and national recognition.

The American River Parkway is planned to include a 12-square-mile recreational and open space greenbelt along 30 miles of the American River floodplain from Folsom Dam to the Sacramento River. The county has primary parkway responsibility for the 23-mile reach of stream from Nimbus Reservoir to the mouth of the American River, including the portion within the City of Sacramento. The Plan would preserve the character of natural areas along the river, improved only by additional access, riding and hiking trails. Developed recreation areas would provide for picnicking, swimming, boating, and other types of day-use, plus several camping locations along the river.

In April 1972, the State Water Resources Control Board issued Decision 1400, which provided that flows of not less than 1,250 cfs be maintained in the entire reach of the American River from Nimbus Dam to its mouth from October 15 to July 14, reducing to 800 cfs July 15 to October 14 for maintenance of fish and wildlife; from May 15 to October 14 flow would be increased to 1,500 cfs for recreational purposes. These flows are non-consumptive in that they are available at the mouth of the American River in pristine condition for other beneficial uses. The State Water Resources Control Board found that these flows are needed for the protection of fish and wildlife and for recreational purposes.

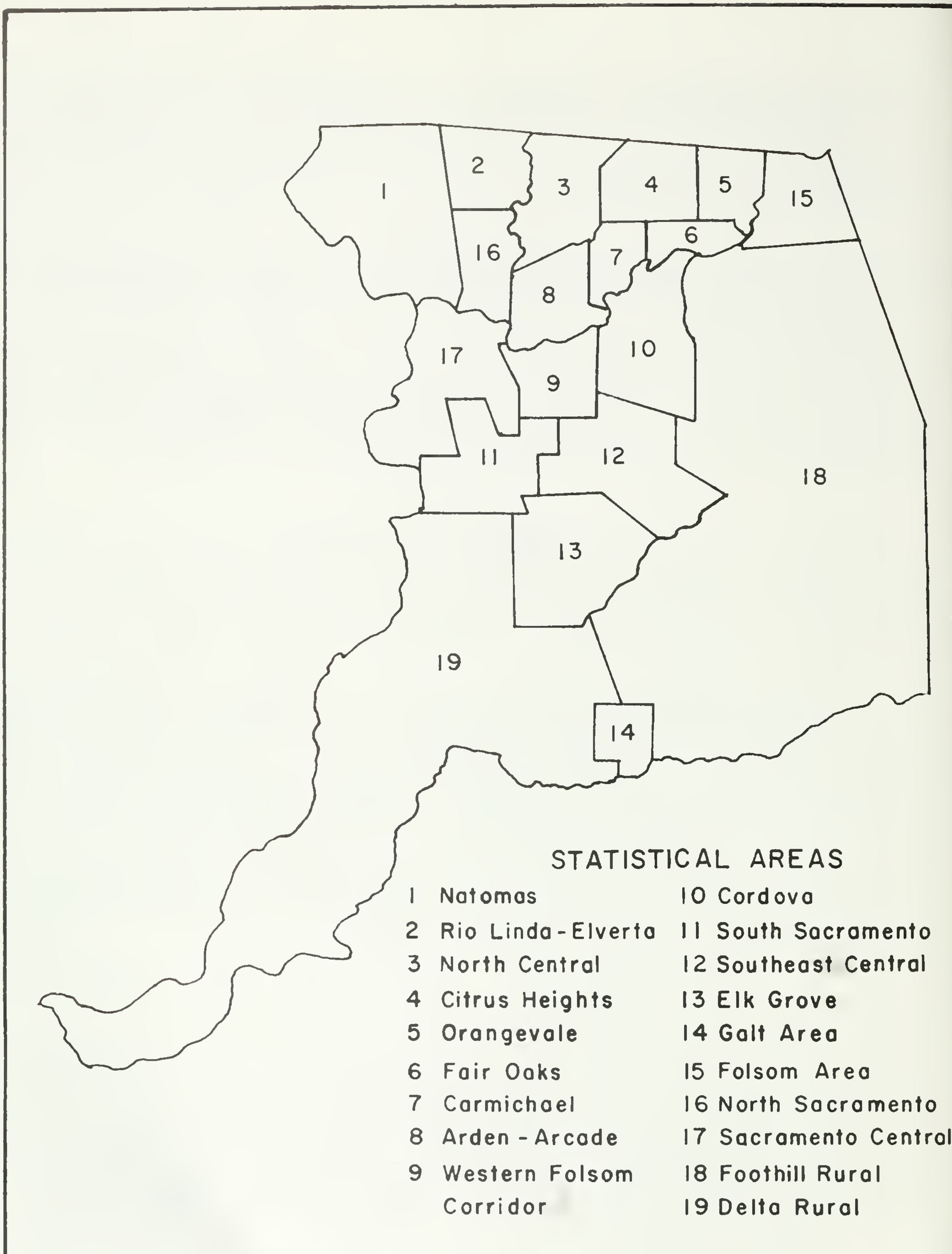


Figure 7. SACRAMENTO COUNTY STATISTICAL AREAS

Table 4

POPULATION PROJECTIONS* BY STATISTICAL AREAS
FOR SACRAMENTO COUNTY

Statistical Areas	1970 Census	Projected 1980	1990	2000	Holding Capacity (Urban Areas)
1. Natomas	8,759	23,010	40,520	59,640	113,000
2. Rio Linda-Elverta	12,694	15,470	18,860	22,990	40,400
3. North Central	48,403	61,950	74,770	87,510	98,000
4. Citrus Heights	42,032	56,490	70,920	85,590	140,000
5. Orangevale	17,222	22,040	26,870	31,800	42,500
6. Fair Oaks	15,463	20,780	26,600	32,420	50,000
7. Carmichael	37,625	47,690	53,730	56,480	62,000
8. Arden-Arcade	85,272	96,080	103,020	108,300	120,000
9. Western Folsom Corridor	18,678	29,730	38,050	47,300	58,600
10. Cordova	38,267	50,430	61,470	71,340	80,000
11. South Sacramento	44,203	61,160	78,280	95,420	151,500
12. Southeast Central	2,670	3,590	4,820	6,480	---
13. Elk Grove	5,717	7,680	9,830	12,580	31,000
14. Galt Area	4,371	6,160	7,880	9,890	18,500
15. Folsom Area	8,189	9,050	10,000	11,050	60,000
16. North Sacramento	41,763	43,930	46,180	48,550	102,700
17. Sacramento Central	188,296	192,100	196,000	200,000	312,300
18. Foothill Rural	4,352	5,850	7,490	9,130	20,000
19. Delta Rural	7,532	7,160	7,160	7,530	---
County Total	631,498	760,350	882,450	1,004,000	1,500,500

*Sacramento County Planning Department projections for April 1 of year.

21a	Natomas	25b	Carson & Deer Creeks
21b	Del Paso-San Juan	53a	Sacramento
21c	Mormon Island	53b	Mather-Florin
21d	Nimbus	55a	Delta Rim
22	American	55b	Delta Islands
25a	Alder Creek	59	Cosumnes

Figure 8. SACRAMENTO BASIN & DELTA-CENTRAL SIERRA HYDROLOGIC STUDY AREAS

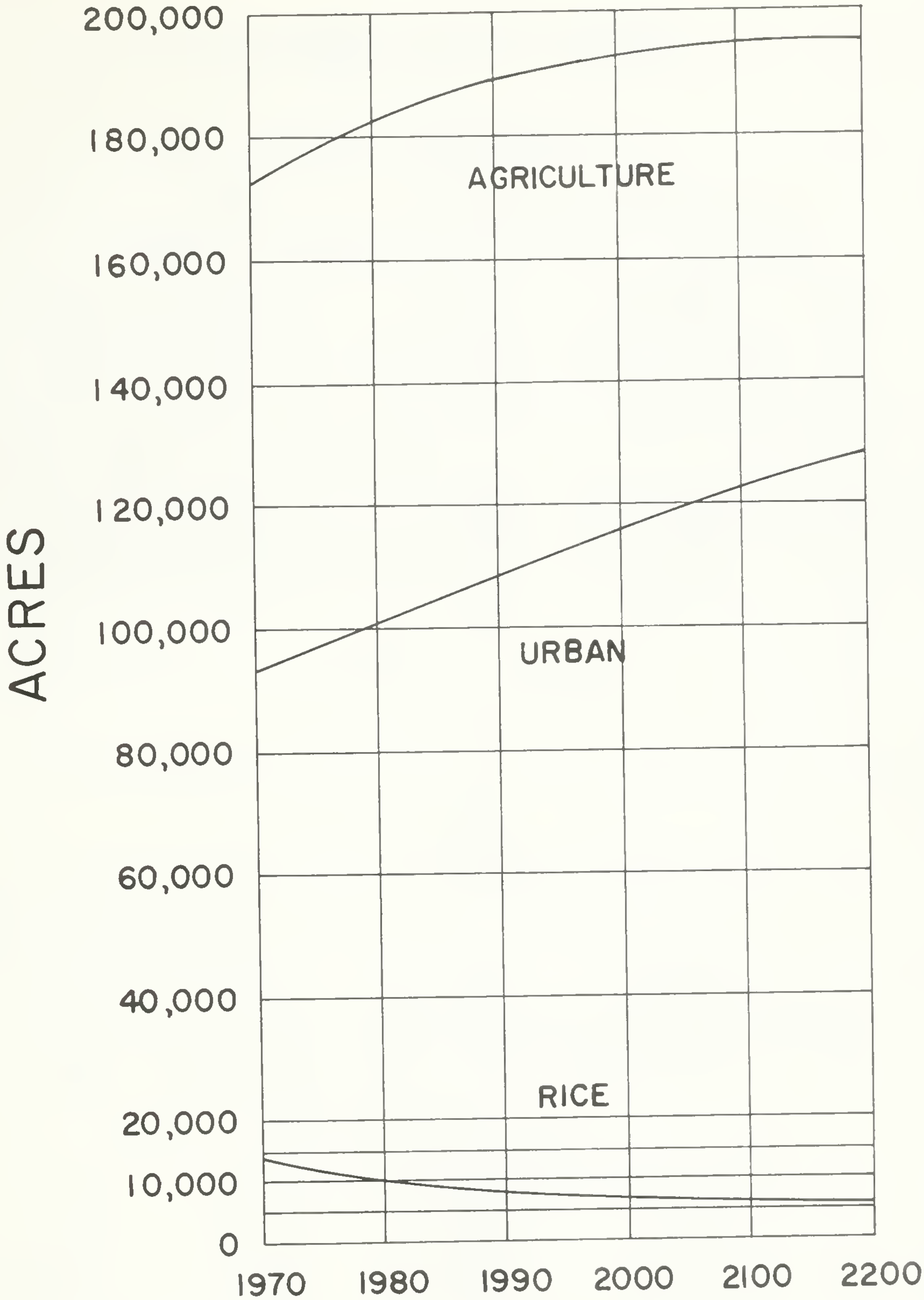


Figure 9. STUDY AREA
PROJECTED LAND USE

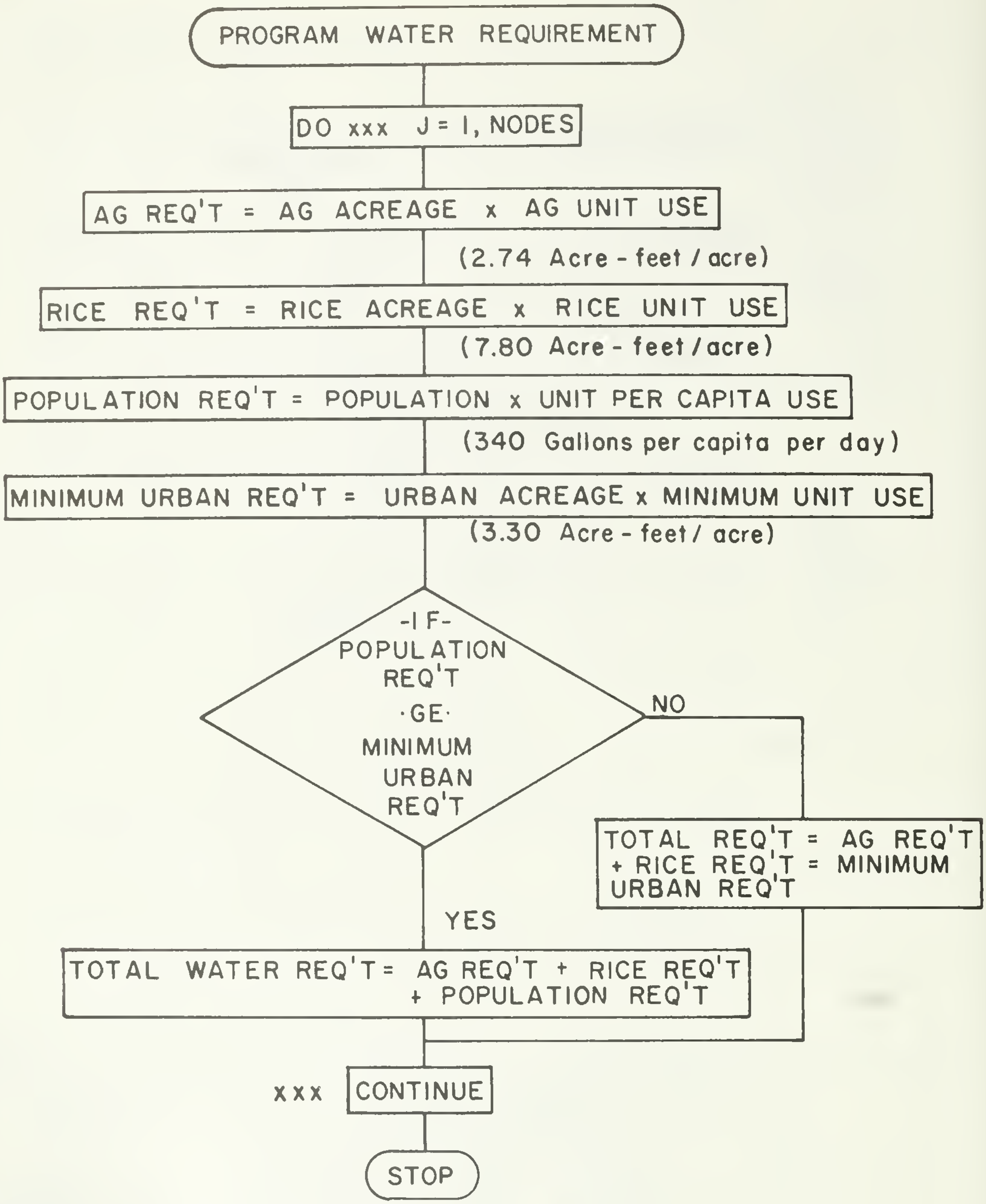


Figure 10 WATER REQUIREMENT FLOW CHART

Table 5

PROJECTED LAND USE

Year	Irrigated Agriculture* Acres	Irrigated Rice Acres	Urban Acres
	Study Area		
1970	173,000	13,700	93,400
1980	183,900	10,500	101,400
1990	191,300	7,700	108,500
2000	193,000	6,600	
2010	196,000	6,500	123,200
2020	196,000	6,300	128,500
	Sacramento County		
1970	163,400	11,800	89,900
1980	175,300	8,900	97,500
1990	182,400	6,500	104,200
2000	184,700	5,600	111,100
2010	187,800	5,500	118,500
2020	188,500	5,300	123,200

* Does not include irrigated rice

Table 6

PROJECTED WATER REQUIREMENT
(in Acre-Feet)

	Irrigation*	Urban**	Total
	Study Area		
1970	585,700	312,800	898,500
1980	591,400	431,800	1,023,200***
1990	591,800	477,300	1,069,100
2000	591,400	526,900	1,118,300
2010	602,000	574,100	1,176,100
2020	598,400	610,100	1,208,500
	Sacramento County		
1970	539,700	300,700	840,400
1980	549,700	415,300	965,000***
1990	550,500	455,400	1,005,900
2000	549,800	499,100	1,048,900
2010	557,500	543,900	1,101,400
2020	557,800	575,700	1,133,500

* Projected irrigation requirement fluctuated due to a combination of an increasing agricultural acreage and a decreasing rice acreage.
** Urban includes Municipal, Domestic, and Industrial uses.
*** Water requirement includes from 1980, 75,000 acre-feet required by SMUD Rancho Seco Project.

CHAPTER III. WATER SUPPLY

During the study period (1962 through 1968) the average annual water demand was 771,900 acre-feet, of which 557,000 acre-feet was for irrigation and 214,900 acre-feet was for municipal and industrial purposes. Water supplies to meet the various demands in the study area consisted of locally pumped ground water and local surface water diversions (see Figure 5). In 1970, 44 percent of the water demand was satisfied from ground water sources and 56 percent from surface water sources.

Surface Water

Most of the surface water used in the County is diverted from the Sacramento and American Rivers directly into irrigation works or into treatment plants. A major user of domestic surface water in 1969 was the City of Sacramento, which diverted 34,590 acre-feet from the Sacramento River and 30,380 acre-feet from the American River. During that same year, Arcade Water District also diverted from the American River (2,280 acre-feet), as did Carmichael Irrigation District (8,345 acre-feet), City of Folsom (18,790 acre-feet), and San Juan Suburban Water District (35,430 acre-feet). Agriculture users diverted 306,800 acre-feet in 1969, most of which came from the Sacramento River.

The Sacramento County Water Agency currently is negotiating for approximately 250,000 acre-feet of the future water supplies to be táken from the Folsom South Canal. The above-mentioned water users all have contracts or commitments for additional surface water supplies. If all the proposed federal projects listed in this chapter are completed, a future total of 1,329,000 acre-feet of surface water would be available to Sacramento County.

Ground Water

To estimate the potential supply of ground water available to meet the needs of Sacramento County, the amount of ground water in storage at the start of the study period and the future replenishment rate must be determined.

In the study area, ground water is contained in unconsolidated to consolidated sedimentary materials comprised of gravel, sand, silt, and clay. These water-bearing materials are underlain by consolidated rocks which generally contain unpotable water. At certain locations throughout the County, unpotable saline water is encountered. The lowest principal level in which fresh water is found is termed the base of fresh water. This level is defined as containing water with total dissolved solids (TDS) not exceeding 2,000 milligrams per liter (3,000 micromhos conductivity). Because the surface representing the base of fresh water is highly irregular, it was decided that a planar representation of this base should be chosen for the purposes of the ground water model. Examination of geochemical data indicated that the Mehrten Formation generally contained potable ground water, while the Valley Springs and other underlying formations generally contained unpotable water. Thus, it was decided that, for the purposes of the ground water model, the base of the Mehrten Formation would represent the base of fresh water. Figure 11 presents a contour map showing the elevation contours on the base of the Mehrten Formation.

A study of water quality data indicates that near-surface ground water has a TDS of about 200 mg/l. This level of TDS was found to extend to depths of from 400 to 500 feet in Sacramento County. Below these depths, TDS appears to increase until the base of fresh water is reached, where TDS is 2,000 mg/l. The nature of this increase with depth is not known. Ground water studies in other parts of the State have indicated that this increase is not of a gradual nature. Rather it is fairly abrupt, with zones of low TDS being interfingered between zones of much higher TDS.

Ground water with TDS of less than 750 mg/l presents no problem for agricultural use. However, water with TDS ranging from 750 to 3,000 mg/l may present serious problems when used for agricultural purposes. Ground water with TDS of more than 3,000 mg/l is considered unsuitable for agricultural uses. According to Title 17, Part 1, Chapter 5, Subchapter 1, of the California Administrative Code, water should not exceed a TDS content of 500 mg/l or a specific conductance of 800 micromhos for a high degree of consumer acceptance when used for domestic or municipal purposes. Water with TDS of up to 1,000 mg/l or a specific conductance of up to 1,600 micromhos is acceptable when it is not reasonable or feasible to provide more suitable waters. Water with TDS of from 1,000 to 1,500 mg/l, or a specific conductance of from 1,600 to 2,400 micromhos, is acceptable only for an existing distribution system on a temporary, short-term basis pending construction of treatment facilities or development of acceptable new water sources.

The ground water storage capacity of the study area was determined for each node of the mathematical model by multiplying the average specific yield of each node by the aquifer thickness and the surficial area of the node. The summation of the storage capacity of the nodes indicates that the ground water basin could contain 36.8 million acre-feet of water if saturated to the ground surface. Water level data for 1968 indicate that the actual amount of ground water in storage is 35.3 million acre-feet.

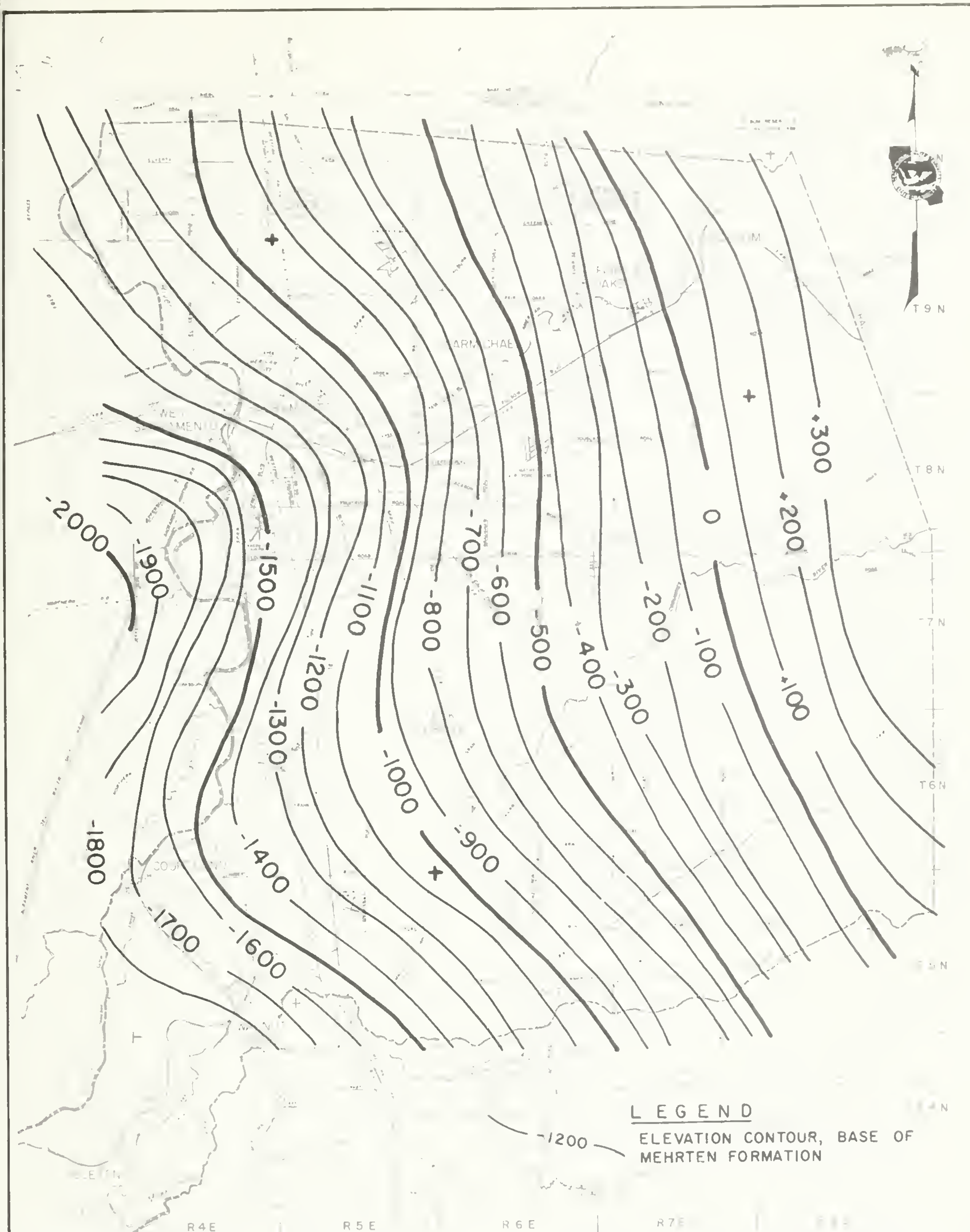


Figure 11. ELEVATION CONTOURS ON BASE OF MEHRTEN FORMATION

Replenishment

The sources of replenishment to most ground water basins includes subsurface inflow, stream infiltration, and deep percolation of water from various sources such as precipitation, irrigation, and water spread in artificial recharging basins or streambeds.

Subsurface inflow to the study area is estimated at the present time to be nil. This is due to natural barriers to subsurface inflow that exist at least until the basin is heavily stressed. These barriers consist of the contact with nonwater-bearing rocks of the Sierra Nevada foothills to the east, ground water mounds caused by Dry Creek to the south and the Sacramento River to the west, and a no-flow condition along the north county line resulting from current pumping practices. The average annual amount of ground water recharge from streams in the study area is estimated to be:

Cosumnes River	43,900	acre-feet per year
American River	40,900	acre-feet per year
Sacramento River	23,800	acre-feet per year
Other Small Streams	12,900	acre-feet per year
Total	121,500	acre-feet per year

The amounts of recharge estimated above for the various streams are not proportional to the flow in those streams. Infiltration from the Sacramento River is restricted by a 20- to 30-foot thick layer of fine sediments derived from hydraulic mining. Recharge along the lower reaches of the American River is probably also restricted by this same hydraulic mining detritus. Furthermore, in the Carmichael area, infiltration along the American River is impeded by flat-lying beds of hard clayey silt, but some horizontal flow from the river may occur into adjacent permeable materials. Hydraulic mining activity in the Cosumnes River drainage basin has been minor. As a result, a higher amount of recharge can occur even though the stream drains a smaller watershed and has a lower total flow.

Deep percolation due to precipitation under existing conditions is estimated to average about 86,800 acre-feet per year. This type of deep percolation tends to decrease when agricultural or fallow (nonused) land is urbanized; it increases when fallow land is cultivated. Deep percolation from surface water application results from the irrigation of lawns, parks, golf courses, and rural agricultural areas. Under present conditions, the deep percolation of this latter type was estimated to be 35,000 acre-feet per year.

No artificial recharge or direct spreading of percolation waters occurs in Sacramento County at the present time. Indirectly, as a result of diversions of surface water from the Cosumnes River by the Omochumne-Hartnell Water District, approximately 2,000 acre-feet per year is infiltrated to the ground water body.

In most ground water basins, ground water is removed both by subsurface outflow and by pumping. Because subsurface inflow and outflow do not occur in significant amounts in Sacramento County, the pumping of ground water is the only significant factor affecting ground water removal. Under present conditions, an estimated 389,500 acre-feet per year is removed from the ground water basin in Sacramento County by pumping. This represents about 45 percent of the delivered water in the study area. In the future, the amount of water to be taken out of the ground water basin by pumping will depend upon the plan of operation to be implemented.

Surface Water Quality

Sacramento County has two abundant surface water supply sources, the American and the Sacramento Rivers. The Cosumnes River, in the southern portion of the County, also is a potential source of surface water, although it is not used to a great extent at the present time.

The mineral quality of water in the American River is excellent; its mineral content is far below the maximum concentrations of constituents for drinking water provided for in the California Administrative Code. The water is calcium-magnesium bicarbonate in nature, with a TDS ranging from 32 to 55 mg/l, and total hardness (TH) ranging from 10 to 50 mg/l. (Representative analyses are shown in Table 7.) Sacramento River water is also of good quality. The TDS values range from 56 to 179 mg/l and TH ranges from 29 to 97 mg/l. With increasing upstream development along the Sacramento River, the TDS of the Sacramento River water is expected to increase somewhat.

The Cosumnes River, when developed, is expected to present a third source of high-quality surface water to Sacramento County. The constituents from this source are similar to that of the American River; TDS values range from 32 to 66 mg/l and TH from 16 to 59 mg/l.

Ground Water Quality

Ground water in the study area of Sacramento County exhibits a relatively low total mineralization, which seldom exceeds a TDS of 300 mg/l, and averages 200 mg/l. Mean TDS values for Nodes 14-17, 22-25, 30-33, and 38-41, are 213, 182, 210, and 170, respectively, based on 210 samples. When the county area is considered, the mean TDS value increases to 250 mg/l. This increase is due to the influence of the poor-quality ground water in the Delta area.

The chemical character of water in the study area is generally calcium-magnesium or sodium-calcium bicarbonate. The usable ground water body ranges in thickness from several hundred feet near the eastern portion of the County, to an estimated 2,000 feet near the Sacramento River.

In the eastern foothill area, in the vicinity of Michigan Bar, several analyses of water from wells indicated sodium sulfate water apparently from the Ione Formation. The quality of this water ranged from good to poor.

There are discrete zones of poor quality water at relatively shallow depths near the Sacramento Metropolitan Airport, south of the City in the Pocket area (vicinity of Node 46, Figure 4), and at other points along the west boundary of the County. These zones are highly localized, and there is some speculation that they may be associated with geologic structures related to natural gas. If this is the case, the poor-quality water is the result of deep-seated connate water moving upward into the fresh water body. A detailed subsurface geologic investigation of the areas would be needed to verify this condition.

The Delta area contains a separate body of poor quality ground water, which ranges from sodium bicarbonate to sodium chloride in composition. In many areas this water is unusable for either domestic or irrigation purposes. The boundary between this Delta water and the good quality water is roughly along the township line separating Townships 4 and 5 North.

An additional water quality problem in Sacramento County is that of excessive amounts of iron and manganese. Wells with excessive concentrations of these two mineral constituents appear to be randomly dispersed. Studies to date have not been able to define areal and subsurface locations where this problem occurs. The probable causes of excessive iron and manganese are discussed in some detail in Bulletin 118-3. Table 8 presents representative analyses of ground water in Sacramento County.

Existing Facilities

Water supply facilities considered in this report are those required for the transmission and storage of surface and ground waters to meet fluctuating demands. As the first step in developing and testing alternative plans to supply the future water demands of Sacramento County, the existing and previously proposed water supply facilities in the study area were evaluated.

Within Sacramento County there are 21 municipal water purveyors each having over 200 service connections; there also are many smaller water purveyors. Forty-six of the largest water purveyors, including users of agricultural water, are listed in Table 9. Their major facilities are shown on Figure 12, and their service areas are shown on Figure 13.

Table 7

SURFACE WATER QUALITY AT SELECTED STATIONS

Station Number	A0 7175.00	B0 1125.00	B9 1849.80
Station Name	American River at Fair Oaks	Cosumnes River at McConnell	Sacramento River at Freeport
Date	10-27-69	04-29-70	06-08-66
Time	0730	0730	1445
Temperature	58°F	51°F	69°F
pH	6.8	7.3	7.7
Electrical Conductivity (Micromhos at 25°C)	40	75	208
Turbidity	5E	3E	--
Chemical Constituents in Milligrams per Liter:			
Calcium	4.7	5.9	17
Magnesium	1.1	3.6	7.2
Sodium	1.6	3.9	15
Potassium	0.8	1.2	1.0
Carbonate	0.0	0.0	2.0
Bicarbonate	20	40	89
Sulfate	0.0	9.4	15
Chloride	1.4	0.4	10
Nitrate	0.1	0.0	1.9
Boron	0.00	0.00	0.00
Total Dissolved Solids	36	66	131
Total Hardness	16	29	72

Table 8

RANDOMLY SELECTED GROUND WATER QUALITY ANALYSES

Well Location	T06N/R07E-28H01 (Node 82)	T07N/R05E-12P01 (Node 49)	T09N/R05E-36R01 (Node 24)
Date	08-06-70	08-06-70	08-07-70
Time	0830	1400	1330
Well Depth (feet)	279	285	320
Temperature	69°F	70°F	71°F
pH	8.1	8.3	8.3
Electrical Conductivity (Micromhos at 25°C)	157	202	344
Chemical Constituents in Milligrams per Liter:			
Calcium	7.8	13.0	30.0
Magnesium	5.5	9.4	18.0
Sodium	15.0	18.0	12.0
Potassium	1.6	2.2	5.0
Bicarbonate	64	120	167
Carbonate	0.0	0.0	0.0
Sulfate	2.0	0.0	4.4
Chloride	7.6	5.5	17.0
Nitrate	8.4	0.0	9.6
Boron	0.0	0.0	0.0
Total Dissolved Solids	146	128	203
Total Hardness	42	71	147

Table 9

WATER PURVEYORS IN SACRAMENTO COUNTY

No.*		No.*	
1	Natomas Central Mutual Water Company	26	ELK GROVE WATERWORKS
2	Natomas Riverside Mutual Water Company	27	Areas in County Served and Maintained by City of Sacramento
3	RIO LINDA COUNTY WATER DISTRICT	28	Hood Improvement Company
4	Linwood Water Maintenance District	29	Barnes Water Company
5	CITIZEN UTILITIES COMPANY OF CALIFORNIA	30	Lincoln Chan Water Company
6	CITRUS HEIGHTS IRRIGATION DISTRICT	31	Herzog Water Company
7	SAN JUAN SUBURBAN WATER DISTRICT**	32	Delta Telephone and Telegraph Company
8	ARCADE COUNTY WATER DISTRICT	33	Snow Water Company
9	Sacramento Water Company Plant No. 1	34	Locke Mutual Water Company
10	NORTHRIDGE PARK COUNTY WATER DISTRICT	35	Delta Estates Mutual Water Company
11	ARVIN WATER COMPANY	36	Alex Brown Company
12	ORANGEVALE MUTUAL WATER COMPANY	37	Grove Water Company
13	FAIR OAKS IRRIGATION DISTRICT	38	Dye Water Company
14	Dunmovin Heights Mutual Water Company	39	El Ranchito Mutual Water Company
15	CARMICHAEL IRRIGATION DISTRICT	40	RANCHO MURIETTA-EL DORADO IRRIGATION DISTRICT
16	DEL PASO MANOR COUNTY WATER DISTRICT	41	CITY OF SACRAMENTO
17	ARDEN WATER SERVICE - SOUTHERN CALIFORNIA WATER COMPANY	42	CITY OF FOLSOM
18	ARDEN PARK VISTA WATER MAINTENANCE DISTRICT	43	Omochumne-Hartnell Water District
19	CORDOVA WATER SERVICE - SOUTHERN CALIFORNIA WATER COMPANY	44	Galt Irrigation District
20	Wherry Corporation - United States Air Force	45	CITY OF GALT
21	Southwest Tract Water Maintenance District	46	Clay Water District
22	FRUITRIDGE VISTA WATER COMPANY		
23	Tokay Park Water Company		
24	FLORIN COUNTY WATER DISTRICT		
25	Valley Hi Green Water Maintenance District		

* Number refers to reference on Figure 13.
** Officially, San Juan Suburban Community Services District.
Water Purveyors typed in caps have more than 200 service connections.

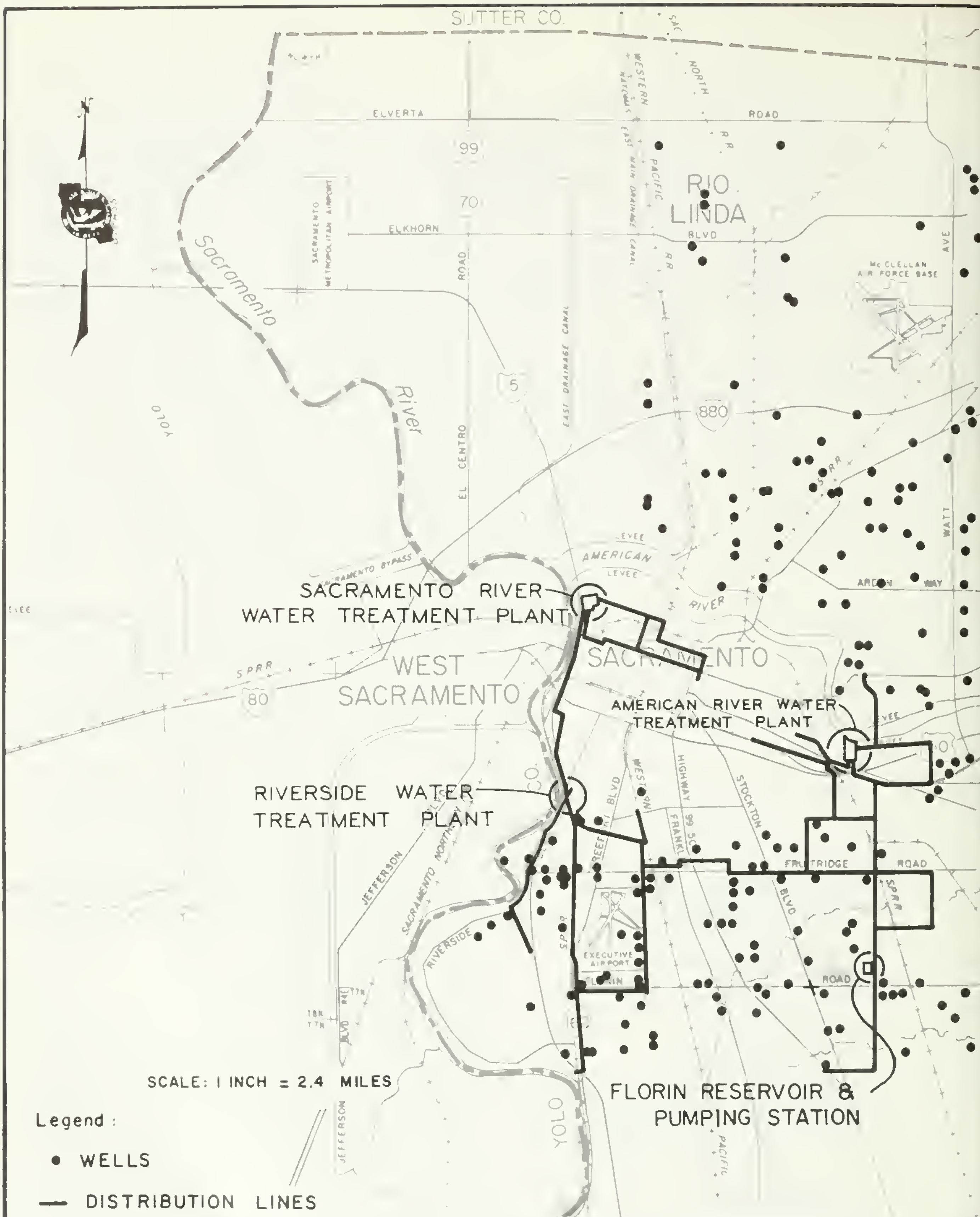


Figure 12. MAJOR DISTRIBUTION LINES & MUNICIPAL AND INDUSTRIAL WELLS

SHEET 1 of 2

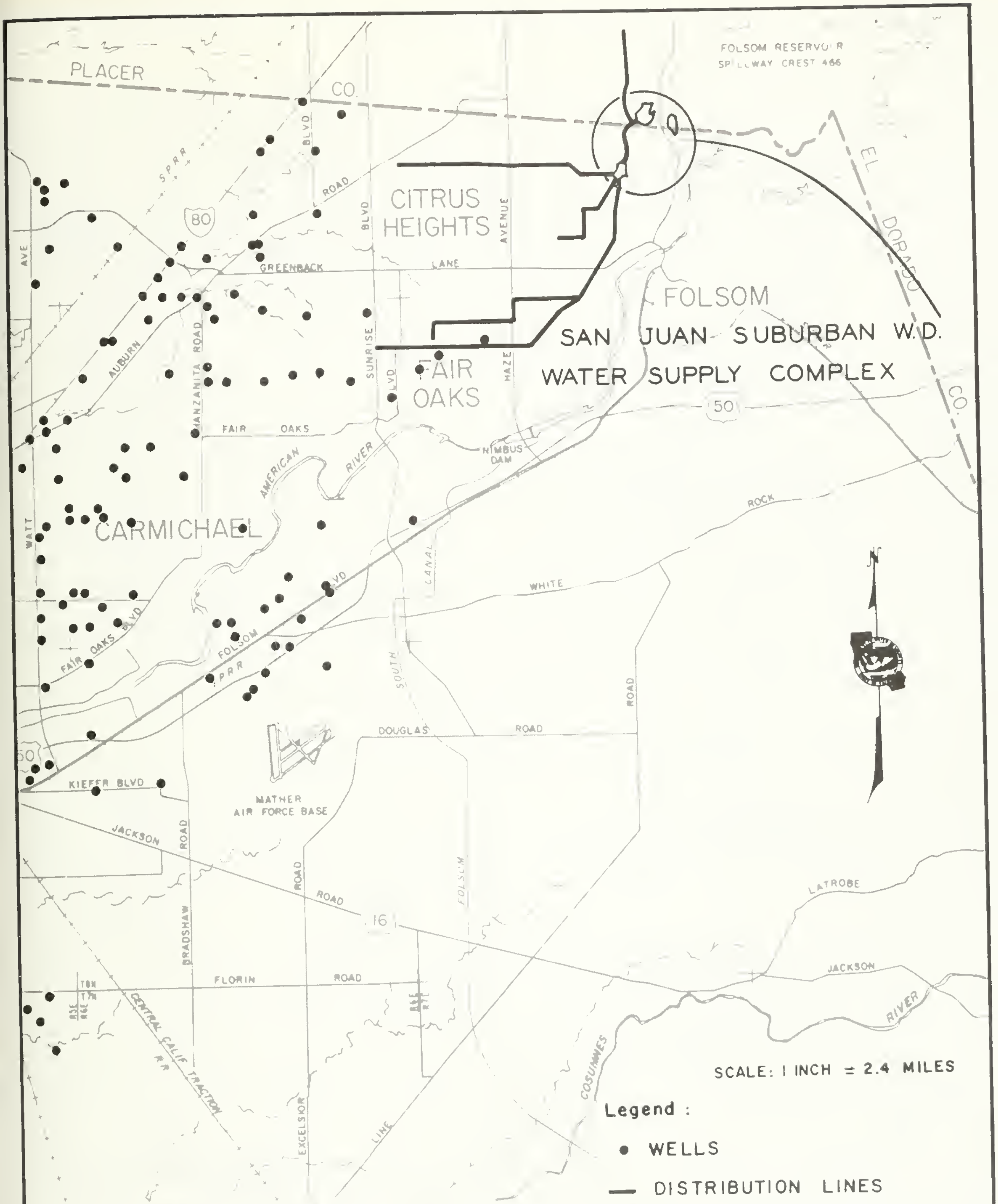


Figure 12. MAJOR DISTRIBUTION LINES & MUNICIPAL AND INDUSTRIAL WELLS

SHEET 2 of 2

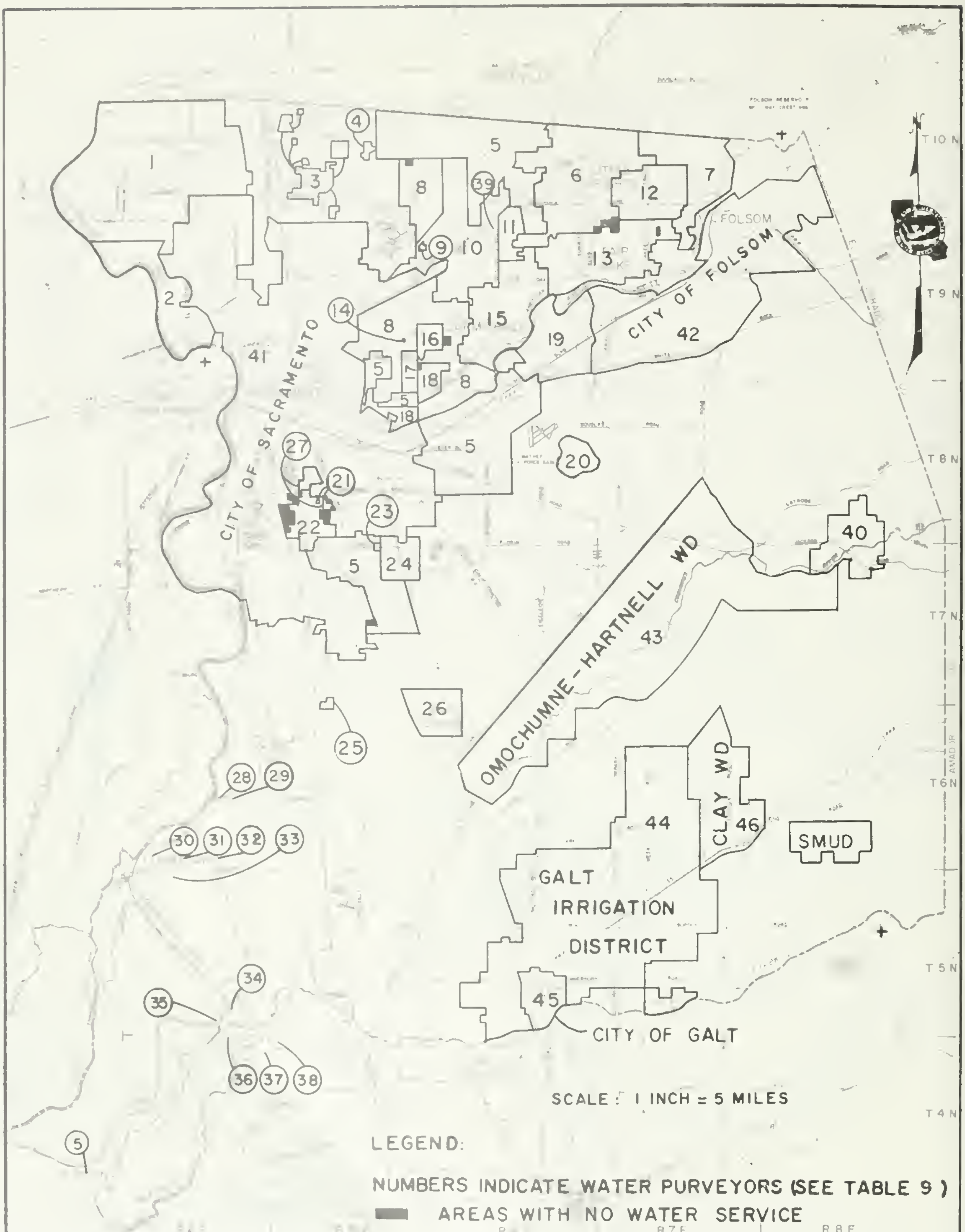


Figure 13. AREA SERVED BY COUNTY, MUNICIPAL, & PRIVATE WATER DISTRICTS

Surface Water Facilities

Surface water facilities include both storage and conveyance systems. In some irrigation districts, natural channels are used to convey water from a storage reservoir to a point where it can be diverted into the distribution system. The operation of districts delivering surface water is described in the following section. The availability of surface water is discussed under Present and Future Water Sources.

The principal surface water storage facilities in the Sacramento County area are Folsom Reservoir and Lake Natomas. The only major distribution pipelines in the County are in the City of Sacramento and San Juan Suburban Water District service areas. Major distribution lines are considered those capable of conveying water between different portions of the County in contrast to local distribution lines, which serve only specific areas. In general, the major lines shown in Figure 12 are those with a diameter of 48 inches or larger.

San Juan Suburban Water District diverts water from Lake Folsom into Hinkle Reservoir, where the water is chlorinated and clarified with alum coagulation. The District sells water to Fair Oaks Irrigation District, Citrus Heights Irrigation District, Orangevale Mutual Water Company, and to that part of the City of Folsom north of the American River. The District also retails water to small areas in Sacramento and southern Placer Counties.

Fair Oaks and Citrus Heights Irrigation Districts supplement their surface water supplies by pumping ground water to maintain pressure during peak demand.

The City of Folsom uses surface water diverted from Lake Folsom for its service area south of the American River; it also has two wells located east of Sunrise Boulevard, south of the American River.

The City of Sacramento, the largest municipal and industrial water supplier in the County, has three water treatment plants, two located adjacent to the Sacramento River and one adjacent to the American River. The City of Sacramento has adequate water rights on the Sacramento and American Rivers to meet the ultimate water needs of the City. The City has discontinued all use of ground water for municipal and industrial purposes south of the American River, except for two wells in the Valley Hi subdivision. North of the American River, the City still utilizes ground water. Plans are presently being drawn to expand the output of the Sacramento River Plant to supply the north portion of the City with surface water by 1980.

Carmichael Irrigation District pumps American River water from four Ranney Collectors and maintains pressure in the distribution system with ground water. Also, Carmichael Irrigation District receives some surface water from San Juan Suburban Water District through Fair Oaks Irrigation District.

The principal source of water for Arcade County Water District is ground water. The District also operates a collector gallery in the American River channel.

Rancho Murietta is served by El Dorado Irrigation District and uses surface water diverted from the Cosumnes River supplemented by releases from Jenkinson Lake in El Dorado County.

Omochumne-Hartnell Water District purchases agricultural water from the Bureau of Reclamation on an interim basis, using the natural channels of Deer Creek and Cosumnes River as their distribution system.

Natomas Mutual Water Company pumps agricultural water from the Sacramento River and Cross Canal at five different diversion points -- two on the Cross Canal and three on the Sacramento River -- into their gravity distribution canal system. The company diverts about 100,000 acre-feet of water annually.

Ground Water Facilities

The majority of the water purveyors in Sacramento County use the ground water basin as their only source of water supply.

The ground water system can be considered as analogous to a surface water system. The rate of recharge and subsurface inflow into the ground water reservoir is similar to the rate of inflow into a surface reservoir; the storage capacity of the ground water basin is comparable to the storage capacity of a surface reservoir; and the transmissivity characteristics of the aquifers of the basin may be compared to the delivery characteristics of a surface distribution system. Finally, the ground water table in the basin is analogous to the hydraulic grade line elevation in a surface water distribution system.

The transmissivity and storage characteristics of the aquifers of the basin were analyzed during the geologic and hydrologic phases of the study and have been incorporated into the mathematical model of the basin. The ground water facilities of each of the water purveyors consist of wells, on-line storage tanks, and minor distribution lines. The source of ground water recharge includes streamflow, delivered water, and rainfall, but does not include artificial recharge. The number of wells and estimated capacities of the wells are tabulated by purveyor on Table 10. Pumping capacities of wells are based on production tests made when the well was installed, or after extensive maintenance, and may be higher than rates obtained under normal operation.

Table 10

GROUND WATER FACILITIES

Agency	Number of Wells	Maximum Pumping Rate (Gallons per Minute)
Arcade County Water District	52	46,250
Arvin Water Company	8	6,400
Arden Water Service (Southern California Water Company)	7	4,200
Carmichael Irrigation District	8	10,400
Citizens Utilities Company of California	61	45,635
City of Folsom	2	2,000
City of Galt	6	7,600
City of Sacramento	42	27,800
Citrus Heights Irrigation District	7	8,400
Cordova Water Service (Southern California Water Company)	14	8,400
Del Paso Manor County Water District	7	8,000
Elk Grove Water Works	4	4,000
Fair Oaks Irrigation District	7	6,500
Florin County Water District	7	7,000
Fruitridge Vista Water Company	13	10,000
Mather Air Force Base	15	9,275
McClellan Air Force Base	21	12,700
Northridge Water District	15	17,430
Rio Linda Water District	6	2,655
Sacramento County Maintenance District	17	15,000

The locations of wells in the area from Township 8 North to the northern county line are shown on Figure 12.

Minor Facilities

In addition to the major water facilities, there is a group of minor facilities which includes small pipeline distribution systems operated by a number of private and municipal purveyors. These facilities were excluded from consideration in the present study because they are common to all plans of operation and hence do not affect the comparison of the cost of the various alternative plans.

Present and Future Water Sources

As a result of early surface water development, some water purveyors in Sacramento County have sources of surface water. Table 11 is a partial listing of the maximum amounts of surface water various water purveyors in Sacramento County may divert. As far as can be determined, these amounts total approximately 859,200 acre-feet. This amount may be increased to the extent contracts with the U. S. Bureau of Reclamation are executed.

These maximum amounts include riparian, appropriative, and purchased water. All purchased waters are from the U. S. Bureau of Reclamation Central Valley Project; no State Water Project water has been sought or secured by water purveyors in Sacramento County. The entitlements shown are from authorized and completed projects except for the Cosumnes River Project, which, if authorized by Congress and constructed, could provide an additional 55,200 acre-feet of irrigation water and 2,100 acre-feet of municipal and industrial water. This latter project would be a part of the Central Valley Project and would not require extensive dam and reservoir construction. It is not considered likely that the Cosumnes River Project will be authorized in the near future. The Folsom Malby area, a portion of the authorized Auburn-Folsom South Unit of the CVP, will provide 12,500 acre-feet of water; however, this project is not funded nor is it likely to be funded in the near future.

The preceding paragraphs indicate that the total potential water resources available to Sacramento County are adequate to meet all anticipated water demands to the year 2020 and beyond. These resources consist of a large ground water basin, secured surface water supplies through water rights and purchased water, and committed but unsecured surface waters from completed and uncompleted projects.

Table 11

SURFACE WATER ENTITLEMENTS, CONTRACTS, AND DIVERSIONS

(in acre-feet)

Purveyor	Approximate Entitlements & Contracts	Approximate 1969 Diversion	Possible USBR Contracts f/
City of Sacramento	326,500 a/	67,230	
City of Folsom	36,000 b/	18,800	
San Juan Suburban Water District	69,200 a/	35,430	
Natomas Mutual	100,000 a/	90,000	
SMUD	75,000 c/	0	
Carmichael Irrigation District	36,500 a/	8,300	
Other Diversions	216,000 b/	216,000	
Sacramento County Water Agency			
Folsom South Canal Service Area	0	0	320,000 d/
Galt Irrigation District			
Folsom South Canal Service Area	0	0	80,000 e/
TOTAL	859,200	435,760	400,000

a/ Water rights and contracted water.
b/ Water rights.
c/ Contracted water.
d/ Sacramento County currently negotiating for 250,000 acre-feet.
e/ Negotiating.
f/ These amounts are U. S. Bureau of Reclamation estimates and are currently under review by the Department of Water Resources in its review of the California Water Plan.

CHAPTER IV. ALTERNATIVE PLANS FOR MEETING WATER REQUIREMENT

The balanced approach to water resource management in Sacramento County is to satisfy the water demand of the area by utilizing the ground water basin in conjunction with other available water supplies. Of the large number of possible alternative plans that could have been considered for meeting this demand for water, five examples are considered in this study. Each of the plans is evaluated through modeling studies to determine its relative costs.

Political, legal, social, and organizational forces may play a dominant role in the selection of a particular management plan and often override or modify the cost and benefit considerations. Some of these forces are beyond the control of Sacramento County, which further complicates the management problem. Continuation of cooperation between local water organizations, Sacramento County, and other agencies will be helpful in giving consideration to these factors and their additional costs during development of management policies.

Formulation of Alternative Plans

There are two extremes in providing water service. One is to rely exclusively on the ground water basin as a source of water and the other is to use surface water exclusively. Between these two extremes lies a range of possible alternatives, using combinations of surface and ground waters. Operational possibilities for utilizing the ground water in storage could be increased or decreased from its present level or left unchanged, depending upon the operational plan.

A number of physically possible combinations of ground and surface water use were developed for preliminary analysis in meeting the future water needs of Sacramento County. Of these, five plans received detailed economic analysis. In formulating the alternative plans, the following three basic requirements were imposed: (1) the projected water requirement for the study period, 1980 to 2020, will be met; (2) ground water for each alternative plan will be used such that waterlogging or dewatering of aquifers will be kept at a minimum; and (3) surface water will be delivered directly to users.

Description of Example Plans

Plan A continues the present development pattern. All water purveyors now using ground and surface water would continue to provide for their future demand using the same percentage of each as they now use. Those purveyors using ground or surface water exclusively would continue to do so in the future. If adopted, this plan would cause the amount of ground water in storage to decrease. A schematic outline of this plan is shown on Figure 14.

Plan B maximizes the use of surface water available to Sacramento County without regard to institutional problems or to waterlogging of the upper soil profile. It provides for full development of the Folsom South, Malby, and Cosumnes River service areas, conversion of water used for agriculture to municipal and industrial use as needed in the Natomas area, and expansion of the San Juan Suburban Water District service area or a similar district as outlined by Clendenen (1970) and Hill (1962). These two reports describe a plan to bring surface water to all of the North Area. Full utilization of surface water in the City of Sacramento service area also would be accomplished.

Some problems inherent in this plan are the difficulty of assuring full utilization of the Folsom South service area, due in part to the announced intention of the Bureau of Reclamation to increase the price of agricultural water from $2.75 per acre-foot to $6.00 per acre-foot. In addition, pending litigation affecting the flow in Folsom South Canal and in the American River could have an effect on the flow available for the Folsom South service area. Hence, it may not be possible to buy additional surface water or to direct flow assigned from one service area to another, as would be necessary in this plan. Converting agricultural water in the Natomas area to municipal and industrial use also may not be possible. Finally, the Cosumnes River Division, CVP, which is not yet an authorized project, may never be constructed. Implementing Plan B would increase the amount of ground water in storage. This plan is shown schematically in Figure 15.

Plan C provides for the additional surface water use that can be accomplished by minimum facility construction. The City of Sacramento would supply surface water to its service area, limiting the use of ground water to 10 percent. San Juan Suburban Water District would develop as noted in Plan A, and selected areas of the Folsom South service area would receive surface water. The Folsom South service areas receiving water initially would be those areas which could utilize the canal water without extensive diversion works. These would be areas adjacent to the canal, and areas adjacent to streams which cross the canal, into which water can be diverted for downstream use, principally the Cosumnes River and Laguna Creek.

In this plan, the Galt Irrigation District would begin using surface water in 1990, as outlined by Sherman and Sullivan (1972). Ground water levels would continue to decline, but at a slower rate than with Plan A. This plan is shown schematically on Figure 16.

Plan D is idealized without regard to facility cost to replenish the depleted ground storage beginning in 1980 and to restore the ground water basin to full capacity by the year 2020. This plan is similar to Plan B except that smaller quantities of surface water will be applied to areas near the rivers to prevent some of the waterlogging which occurred under Plan B. After the year 2020, ground water demand should equal recharge to maintain relatively stable water levels.

In this plan, surface water was added to each node as needed to bring the ground water surface up to a predetermined elevation, which for the entire basin averaged about 25 feet below the ground surface. Ground water levels were maintained at that elevation by varying the surface supply to match the demand and yield of each nodal area. Sources of supply, existing boundaries, previous rights, etc., were ignored in the plan; hence the term "idealized plan". The main purpose of this plan is to determine the minimum amount of surface water needed to meet the demand if there are no restrictions on where the surface water comes from or where it is used. This plan is shown schematically on Figure 17.

Plan E uses ground water exclusively to satisfy the water demands to the year 2020. This is the most severe condition that could be placed on the ground water basin. It is somewhat idealized, as is Plan D; however, it is much easier to accomplish, since it could be easily done using the present multiplicity of purveyors and is within the scope of present water law. This plan represents extreme conditions as compared to Plan B and it gives water planners a picture of what could happen should each purveyor elect to use ground water exclusively.

This plan dewatered, or essentially dewatered, 29 nodes along the eastern county line. These nodes are in the foothill area where the ground water basin is shallow. To supply water to this area would require a conveyance system from the westerly nodes in the County. Figure 18 depicts this plan.

Earlier in this investigation it was ascertained that 33.7 million acre-feet of water were in storage. Under Plan E, almost 10 million acre-feet of this stored water would be used.

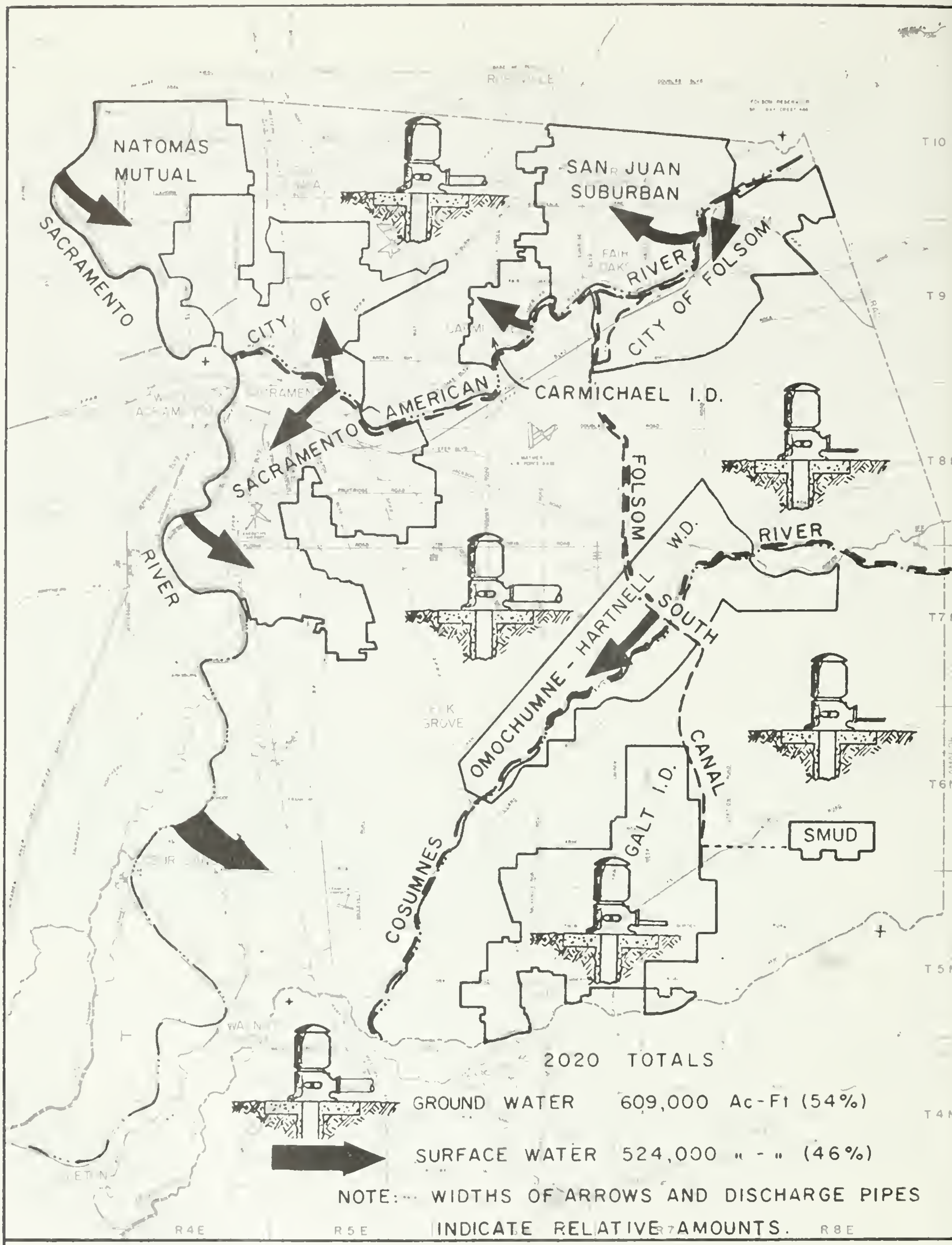


Figure 14. 2020 WATER SUPPLY FOR ALTERNATIVE PLAN A

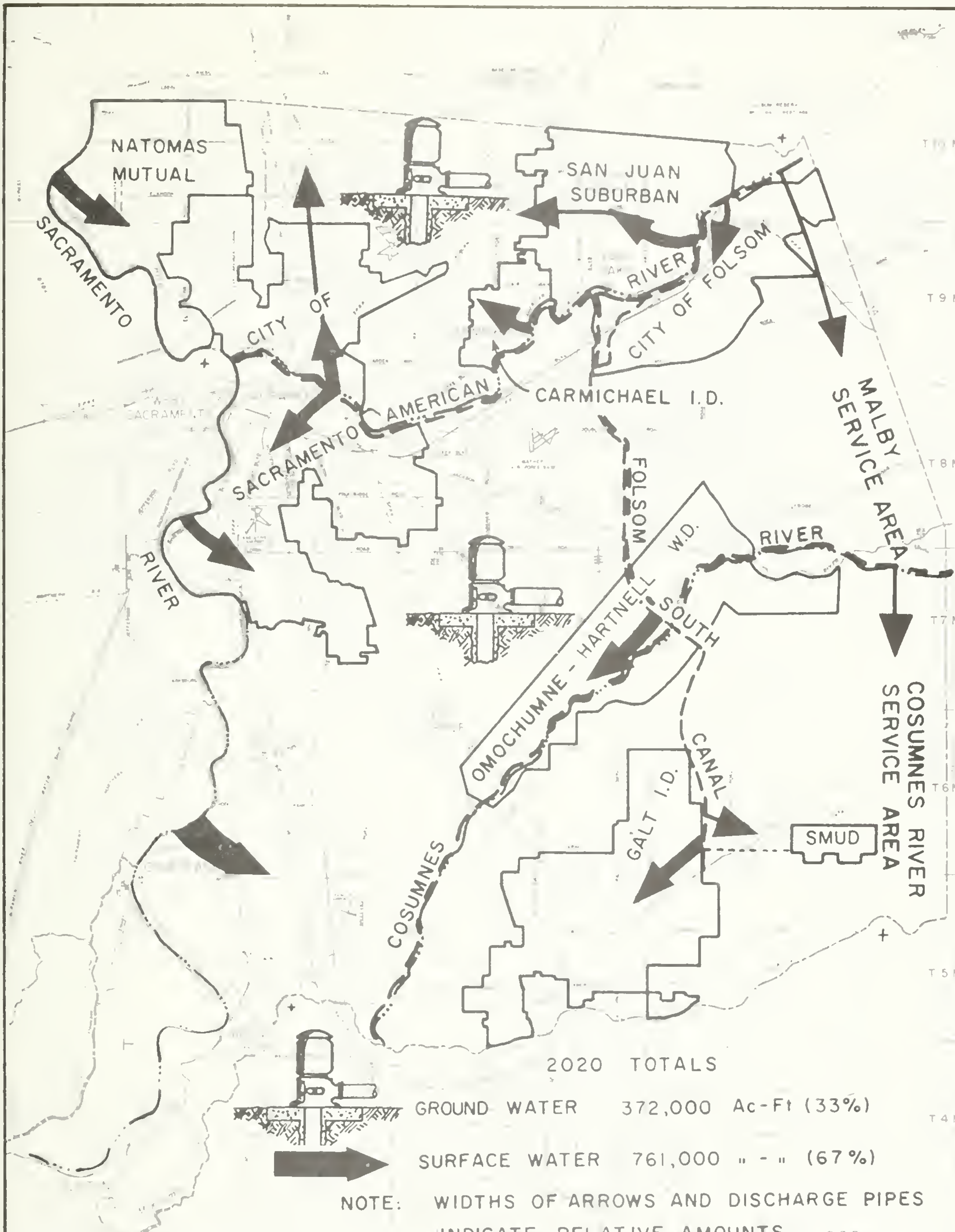


Figure 15. 2020 WATER SUPPLY FOR ALTERNATIVE PLAN B

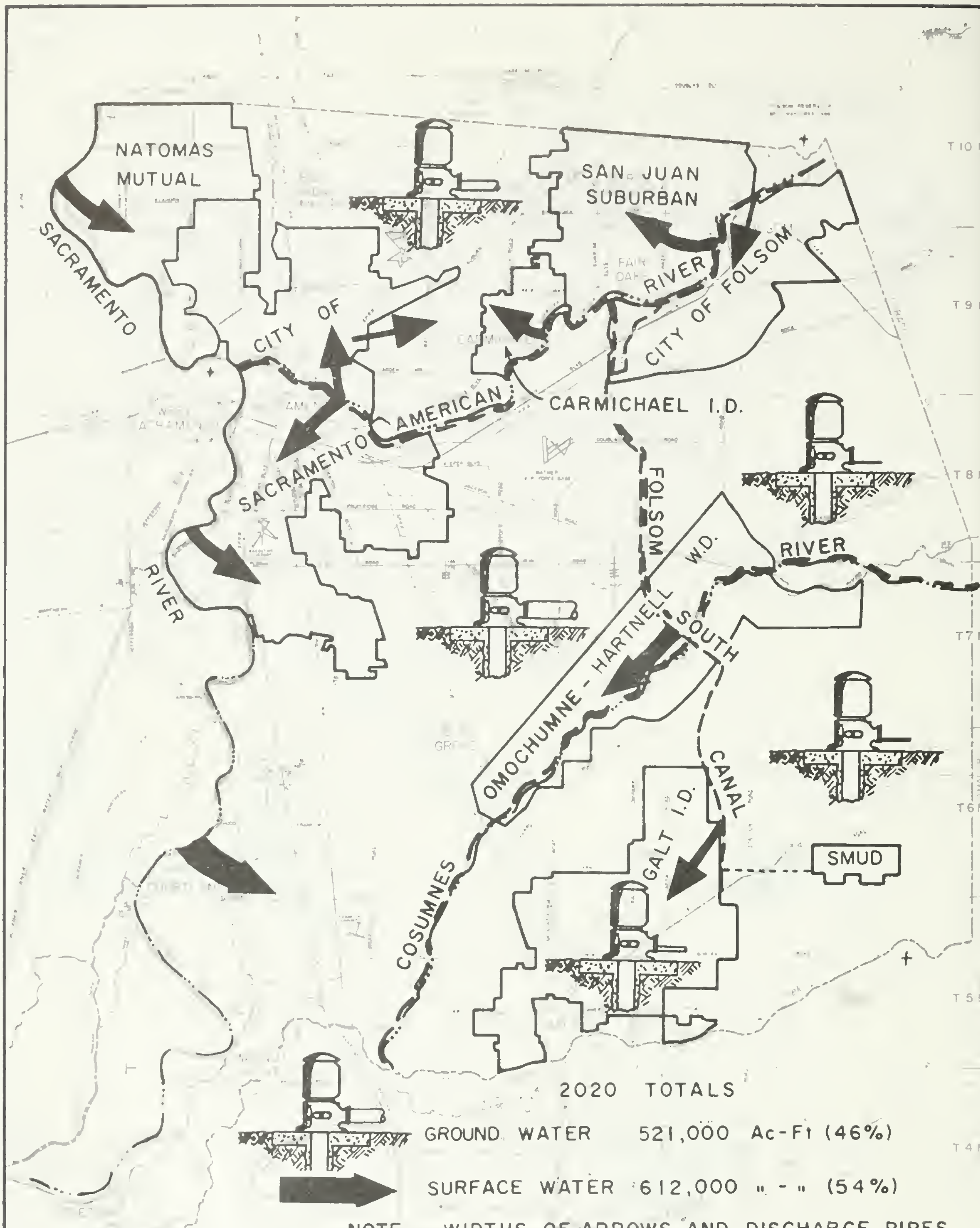


Figure 16. 2020 WATER SUPPLY FOR ALTERNATIVE PLAN C

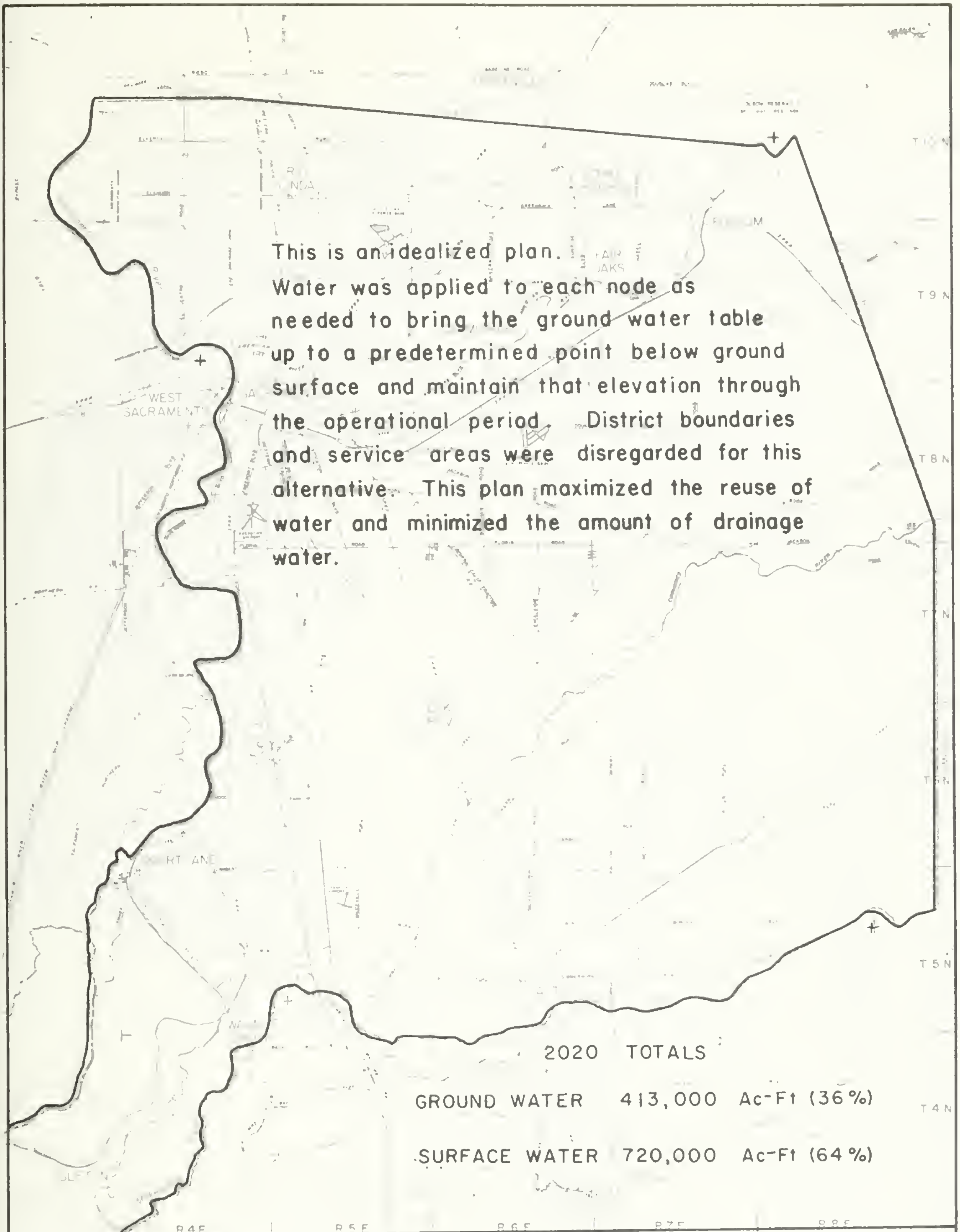


Figure 17. 2020 WATER SUPPLY FOR ALTERNATIVE PLAN D

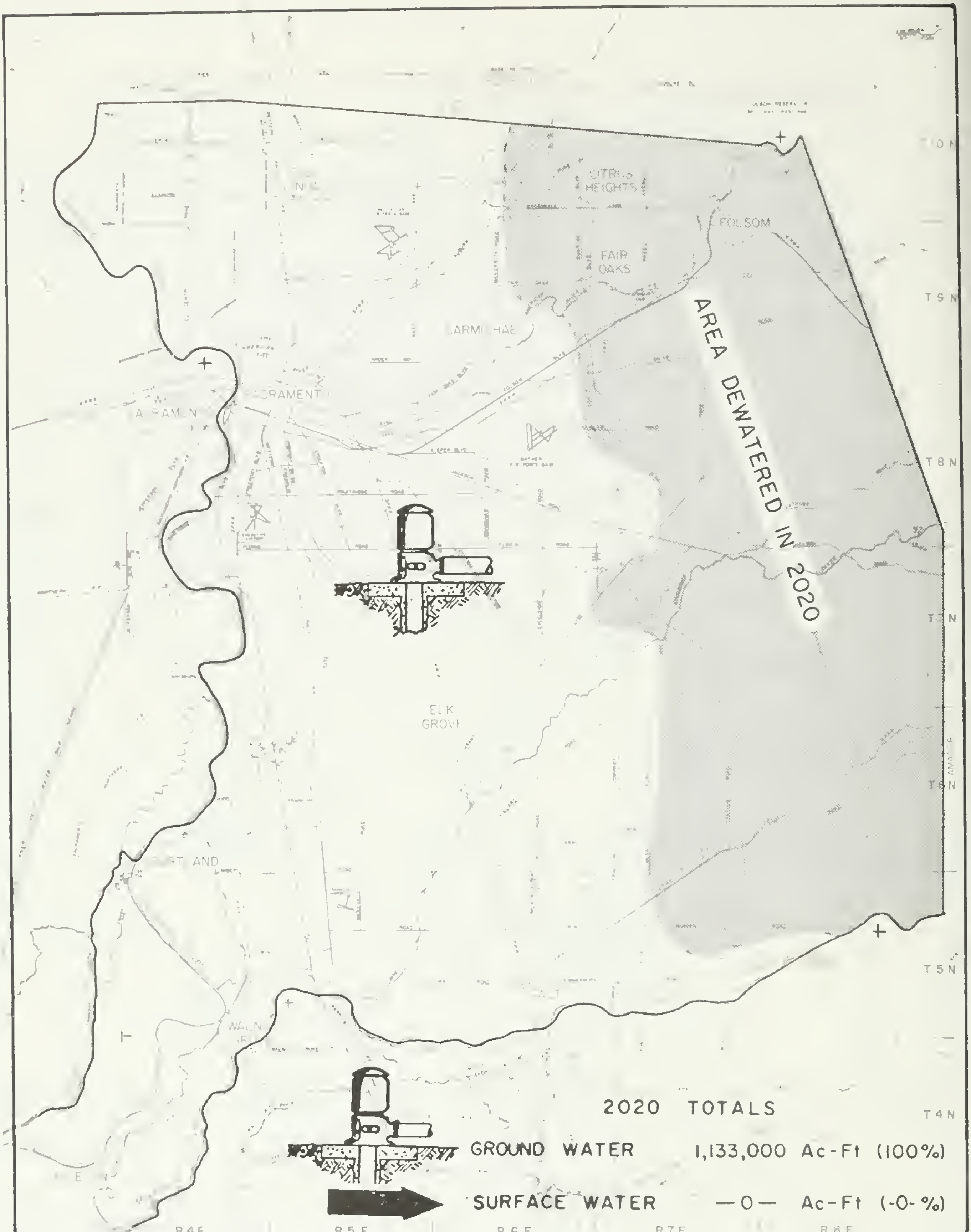


Figure 18. 2020 WATER SUPPLY FOR ALTERNATIVE PLAN E

Physical Effects of Alternative Plans

The five plans of operation selected for economic analysis were tested through use of the mathematical model. The difference between plans is the amount pumped from the ground water basin and the amount diverted from surface water sources. Table 12 summarizes the supply sources to meet total water demand for all five plans. The demands listed are for the beginning of each decade. The percentage of total water demand supplied by ground water ranged from 32.7 percent to 50.1 percent, and that supplied by surface water ranged from 49.9 percent to 67.3 percent.

Table 13 lists the 2020 input data (surface water and ground water) for Operational Plans A, B, C, D, and E. Data for the year 2020 were listed only for comparative purposes to illustrate the differences between plans. A further breakdown of these data is available in the Department of Water Resources files.

Table 12

PROJECTED DEMANDS ON WATER SUPPLY SOURCES
FOR ALTERNATIVE PLANS
(In Acre-Feet)

Year	Plan A		Plan B		Plan C		Plan D		Plan E	
	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water
1970	401,400	497,000	401,400	497,000	401,400	497,000	401,400	497,000	898,400	0
1980	449,500	498,700	264,100	648,100	417,100	531,100	346,500	601,600	948,200	0
1990	490,200	503,900	289,500	704,600	415,100	578,900	360,400	633,700	994,100	0
2000	534,300	508,900	320,900	722,400	454,400	588,900	380,100	663,200	1,043,300	0
2010	581,000	520,000	350,800	750,200	494,800	606,300	399,100	701,900	1,101,000	0
2020	609,200	524,300	372,100	761,500	509,400	624,200	413,100	720,400	1,133,500	0
Total	3,065,600	3,052,800	1,998,800	4,119,800	2,692,200	3,426,400	2,300,600	3,817,800	6,118,500	0
% of Total	50.1	49.9	32.7	67.3	44.2	55.8	37.6	62.4	100	0

TABLE 13

2020 INPUT DATA FOR THE OPERATIONAL PLANS
(In Acre-Feet)

NODE	PLAN A		PLAN B		PLAN C		PLAN D		PLAN E	
	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
1	2,000	11,340	5,340	8,000	2,000	11,340	9,470	3,870	0	13,340
2	16,760	6,780	16,760	6,780	16,760	6,780	16,760	6,780	0	23,540
3	18,520	6,850	18,520	6,850	18,520	6,850	18,520	6,850	0	25,370
4	1,890	9,290	1,890	9,290	1,890	9,290	1,890	9,290	0	11,180
5	1,400	12,950	1,400	12,950	1,400	12,950	1,400	12,950	0	14,350
6	60	18,280	60	18,280	60	18,280	60	18,280	0	18,340
7	1,440	19,040	1,440	19,040	1,440	19,040	1,440	19,040	0	20,480
8	15,560	820	16,370	0	15,560	820	16,370	0	0	16,370
9	8,270	0	7,850	410	8,260	0	8,270	0	0	8,270
10	2,060	0	2,060	0	2,060	0	2,060	0	0	2,060
11	15,750	1,870	15,750	1,870	15,750	1,860	12,620	4,990	0	17,610
12	4,560	8,490	4,580	8,470	4,560	8,490	8,410	4,650	0	13,060
13	9,470	5,520	9,470	5,520	9,470	5,520	9,470	5,520	0	14,990
14	320	5,380	320	5,380	320	5,380	320	5,380	0	5,700
15	4,200	16,810	4,200	16,810	17,860	3,150	21,010	0	0	21,010
16	2,660	15,160	2,660	15,160	2,660	15,160	17,810	0	0	17,810
17	11,730	5,030	11,730	5,030	13,410	3,350	16,760	0	0	16,760
18	12,960	260	13,230	0	12,930	300	13,230	0	0	13,230
19	4,910	0	4,910	0	4,910	0	4,870	30	0	4,900
20	9,400	17,520	9,400	17,520	9,400	17,520	9,400	17,520	0	26,920
21	4,030	12,090	14,510	1,610	4,030	12,090	7,360	8,770	0	16,130
22	14,980	0	13,490	1,500	14,980	0	8,390	6,590	0	14,980
23	1,030	19,650	18,620	2,070	10,340	10,340	20,120	570	0	20,690
24	11,930	7,980	15,930	3,990	15,930	3,990	18,280	1,630	0	19,910
25	3,550	6,590	2,530	7,610	3,550	6,590	5,010	5,130	0	10,140
26	2,370	0	2,370	0	2,370	0	2,370	0	0	2,370
27	2,450	0	2,450	0	2,450	0	2,450	0	0	2,450
28	5,400	4,940	5,400	4,940	5,400	4,940	5,400	4,940	0	10,340
29	7,980	14,800	7,980	14,800	7,980	14,800	9,460	13,320	0	22,780
30	12,060	14,700	25,420	1,340	12,060	14,700	22,750	4,010	0	26,760
31	8,720	8,720	15,690	1,740	8,720	8,720	8,870	8,570	0	17,440
32	6,580	8,060	13,180	1,460	6,580	8,060	3,850	10,790	0	14,640
33	70	8,000	70	8,000	70	8,000	70	8,000	0	8,070
34	0	2,280	0	2,280	0	2,280	0	2,280	0	2,280
35	30	190	30	190	30	190	30	190	0	220
36	10,510	2,710	10,510	2,710	10,510	2,710	7,500	5,720	0	13,220
37	24,920	1,310	26,230	0	24,920	1,310	21,610	4,610	0	26,220
38	10,720	16,000	25,390	1,340	24,050	2,670	24,670	2,050	0	26,720
39	3,480	13,930	15,740	1,680	10,440	6,970	15,740	1,680	0	17,420
40	0	12,590	4,970	7,620	3,790	8,800	4,970	7,620	0	12,590
41	1,530	5,330	1,530	5,330	1,530	5,330	1,530	5,330	0	6,860
42	2,200	2,280	2,200	2,280	2,200	2,280	2,200	2,280	0	4,480
43	1,920	230	1,920	230	1,920	230	1,920	230	0	2,150
44	180	110	180	110	180	110	180	110	0	290
45	10,230	2,020	10,230	2,020	10,230	2,020	7,680	4,560	0	12,240
46	17,060	2,690	17,060	2,690	17,060	2,690	17,060	2,690	0	19,750
47	9,710	6,470	14,560	1,620	9,710	6,470	9,210	6,980	0	16,190
48	620	14,480	620	14,480	620	14,480	12,300	2,800	0	15,100
49	580	3,240	2,670	1,140	580	3,240	1,940	1,870	0	3,810
50	0	6,250	4,130	2,130	0	6,250	2,430	3,820	0	6,250
51	0	6,550	4,330	2,230	0	6,550	4,350	2,200	0	6,550
52	0	4,660	1,650	3,010	0	4,660	1,650	3,010	0	4,660
53	2,320	580	2,330	580	2,320	580	2,910	0	0	2,910
54	450	80	420	110	450	80	530	0	0	530
55	12,090	190	12,090	190	12,090	190	9,400	2,870	0	12,270
56	8,460	2,670	8,460	2,670	8,460	2,670	7,320	3,810	0	11,130
57	1,040	9,050	4,370	5,710	1,040	9,050	4,370	5,710	0	10,080
58	0	10,030	6,490	3,540	0	10,030	6,490	3,540	0	10,030
59	860	7,820	5,730	2,950	860	7,820	5,770	2,910	0	8,680
60	1,890	7,580	6,250	3,220	6,630	2,840	2,820	6,650	0	9,470
61	2,400	5,620	5,290	2,730	5,610	2,410	2,230	5,790	0	8,020
62	1,870	1,420	1,870	1,420	1,870	1,420	3,290	0	0	3,290
63	0	660	0	660	0	660	0	660	0	660
64	0	150	0	150	0	150	0	150	0	150
65	15,410	150	15,410	150	15,410	150	12,410	3,150	0	15,560
66	4,190	4,190	4,190	4,190	4,190	4,190	3,930	4,450	0	8,380
67	740	6,730	4,930	2,540	740	6,730	3,920	3,560	0	7,480
68	0	14,360	9,480	4,880	0	14,360	12,350	2,010	0	14,360
69	0	14,180	9,360	4,820	0	14,180	7,630	6,550	0	14,180
70	5,070	6,240	7,460	3,850	6,780	4,530	2,360	8,960	0	11,320
71	560	5,100	3,730	1,930	2,830	2,830	4,710	950	0	5,660
72	1,770	440	1,460	750	1,770	440	2,210	0	0	2,210
73	500	110	500	110	500	110	500	110	0	660
74	0	150	0	150	0	150	0	150	0	150
75	13,930	250	13,930	250	13,930	250	10,080	4,100	0	14,180
76	11,460	1,270	11,460	1,270	11,460	1,270	9,010	3,720	0	12,730
77	6,840	10,230	11,270	5,800	6,840	10,230	13,880	3,190	0	17,070
78	4,400	10,300	9,700	5,000	4,400	10,300	9,660	5,050	0	14,710
79	0	9,480	6,260	3,220	0	9,480	1,210	8,270	0	9,480
80	630	5,660	4,150	2,140	1,580	4,710	1,100	5,190	0	6,290
81	0	8,760	5,780	2,980	6,130	2,630	4,190	4,570	0	8,760
82	5,210	580	3,820	1,970	5,210	580	4,580	1,200	0	5,780
83	1,380	110	1,380	110	1,380	110	1,380	110	0	1,490
84	160	150	160	150	160	150	160	150	0	310
85	13,880	730	13,880	730	13,880	730	12,570	2,040	0	14,610
86	13,080	1,450	13,080	1,450	13,080	1,450	12,390	2,150	0	14,540
87	8,030	6,570	10,210	4,390	8,030	6,570	11,810	2,790	0	14,600
88	0	16,130	10,640	5,490	0	16,130	3,500	12,630	0	16,130
89	0	5,840	3,860	1,980	0	5,840	0	5,840	0	5,840
90	4,950	9,200	9,340	4,810	4,690	9,460	9,090	5,060	0	14,150
91	3,320	6,180	6,270	3,230	6,650	2,850	6,720	2,780	0	9,500
92	1,050	570	1,070	550	1,140	490	1,510	110	0	1,620
93	840	150	840	150	840	150	840	150	0	990
94	3,250	110	3,250	110	3,250	110	3,250	110	0	3,360
95	12,480	140	12,480	140	12,480	140	9,420	3,190	0	12,610
96	11,580	610	11,140	1,040	11,580	610	8,200	3,990	0	12,190
97	11,840	80	11,840	80	11,840	80	4,700	7,220	0	11,920
98	0	5,800	3,830	1,970	0	5,800	0	5,800	0	5,800
99	2,630	14,990	11,630	5,990	12,330	5,290	12,770	4,850	0	17,620
100	3,920	15,560	12,860	6,620	11,880	7,600	11,880	7,600	0	19,480
101	0	10,510	6,930	3,580	7,350	3,160	8,850	1,660	0	10,510
102	11,110	80	11,110	80	11,110	80	10,390	800	0	11,190
Total	524,350	609,230	761,510	372,080	624,220	509,370	720,440	413,140	0	1,133,580

Change of Ground Water in Storage

By using the mathematical model of the Sacramento County Ground Water Basin, the change in the amount of ground water in storage was determined for each plan of operation. Figure 19 is a plot of the resulting accumulated change in storage from 1970 to 2020 for all five plans.

In 2020, Plans A and C had a negative change in storage and Plans B and D had a positive change in storage from 1970 conditions. Ground water in storage in 1970 was estimated to be 35.5 million acre-feet. Under Plan A, the amount of water in storage in 2020 will be about 33.7 million acre-feet, and under Plan D the ground water basin would have been completely filled, with 37 million acre-feet in storage.

Change in Ground Water Levels

The changes in the ground water levels representing unconfined ground water have a direct relationship to the amount of ground water in storage. Water level elevations were estimated by the mathematical model for each plan of operation. Initial 1970 ground water level elevations are shown in Figure 20. Maps showing contour lines of computed equal changes in ground water levels between 1970 and 2020 for Plans A through D are shown in Figures 21 through 24; Figures 25 and 26 show projected water level elevations for Plans A and C. The figures show that from 1970 to 2020 the following changes in ground water level occur:

1. In Plan A, a general decline of water levels is shown, with the maximum decline of about 90 feet, occurring near Mather Air Force Base.

2. In Plan B, a general increase in water level is shown, with a maximum rise of about 70 feet near Elk Grove.

3. In Plan C, the maximum decline in water level, which occurs east of Mather Air Force Base, is about 50 feet. There also are some increases in water levels on the order of 30 feet in the southeastern part of the County, near Clay.

4. In Plan D, a general increase in water levels is shown, with a maximum of 100 feet near Elk Grove.

5. In Plan E, a general decline of water levels is shown, with a maximum decline of about 434 feet, which occurred in Node 16 located to the east of McClellan Field.

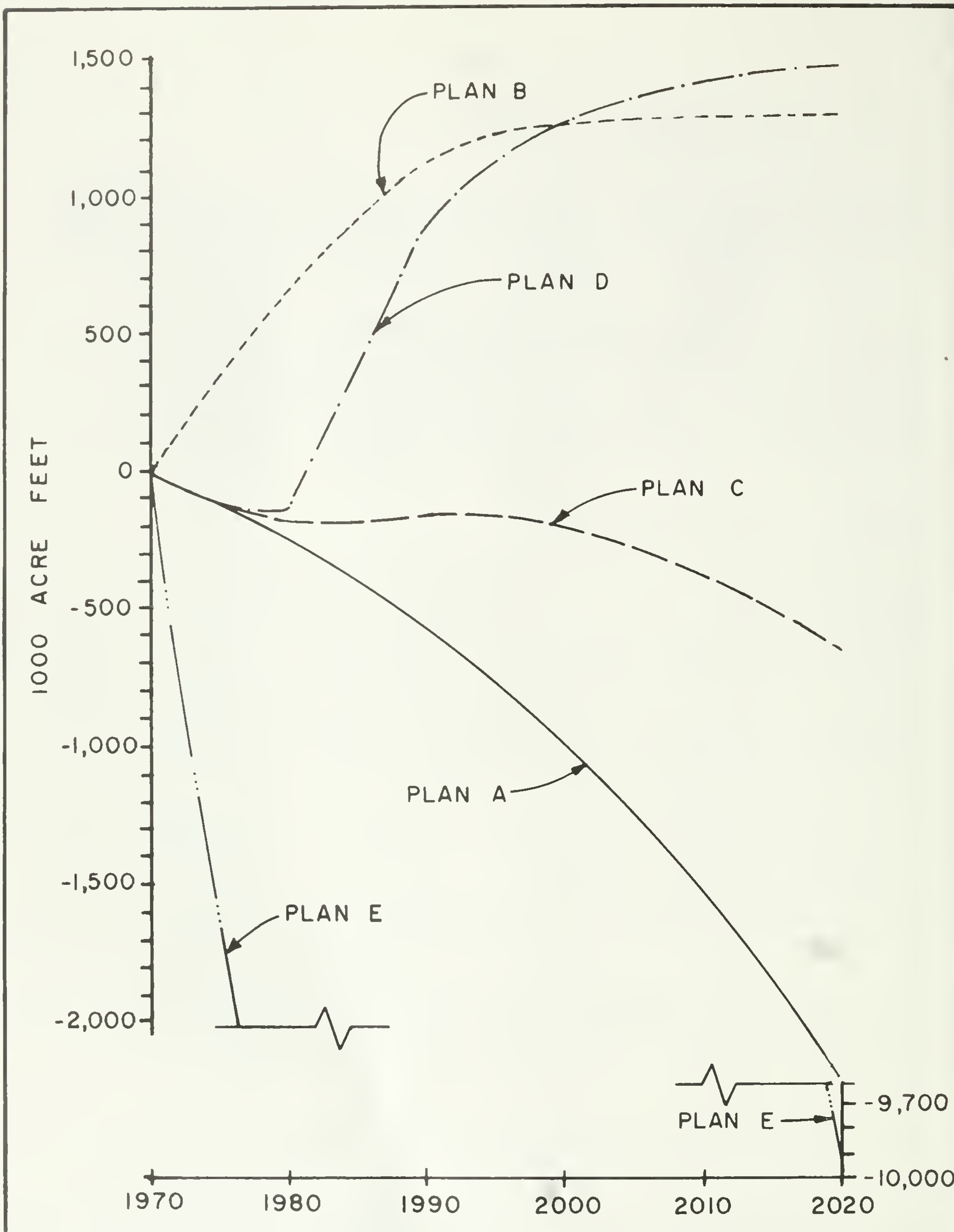


Figure 19. PROJECTED ACCUMULATED CHANGE IN GROUND WATER STORAGE FOR ALTERNATIVE PLANS

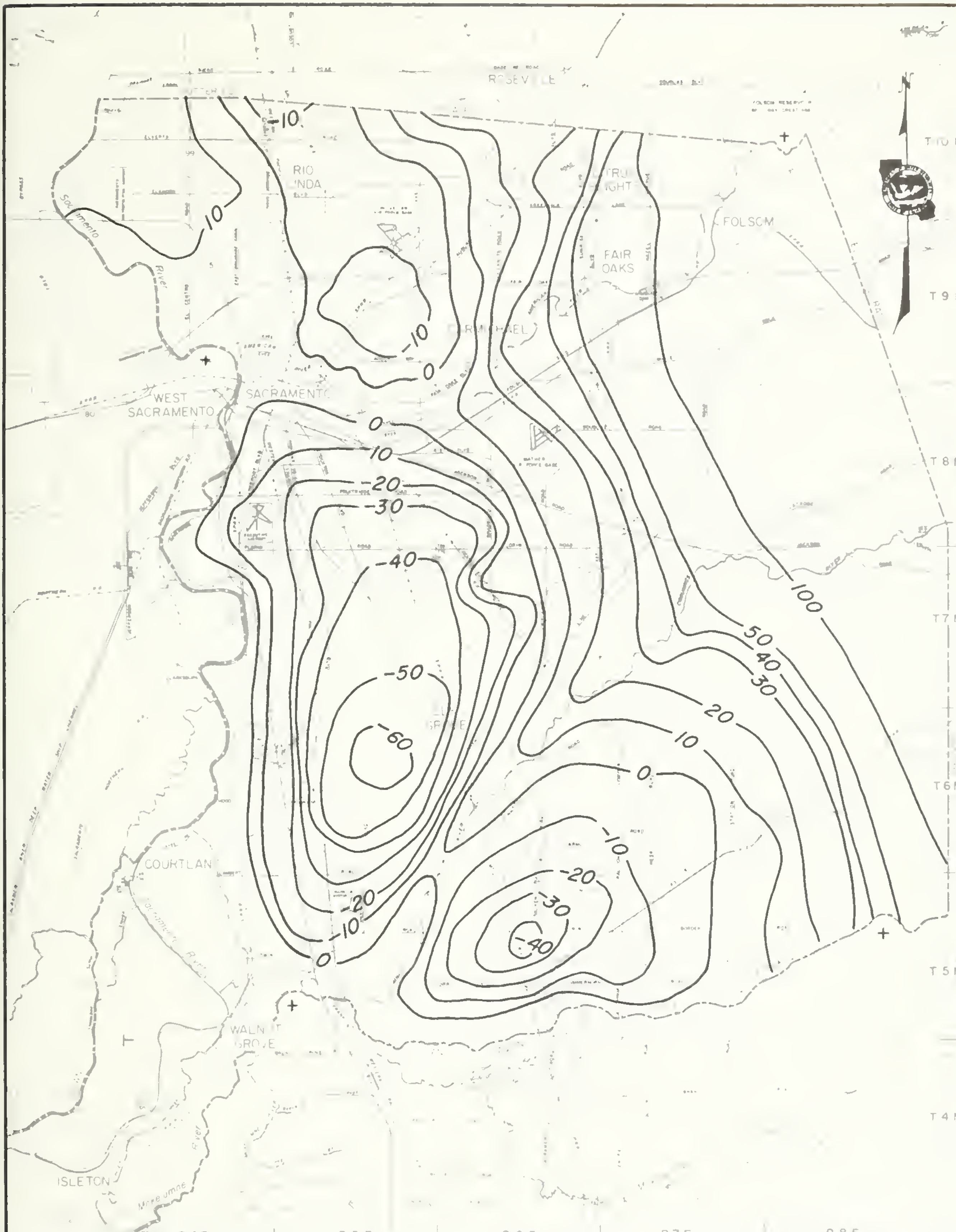


Figure 20. SPRING 1970 WATER LEVELS

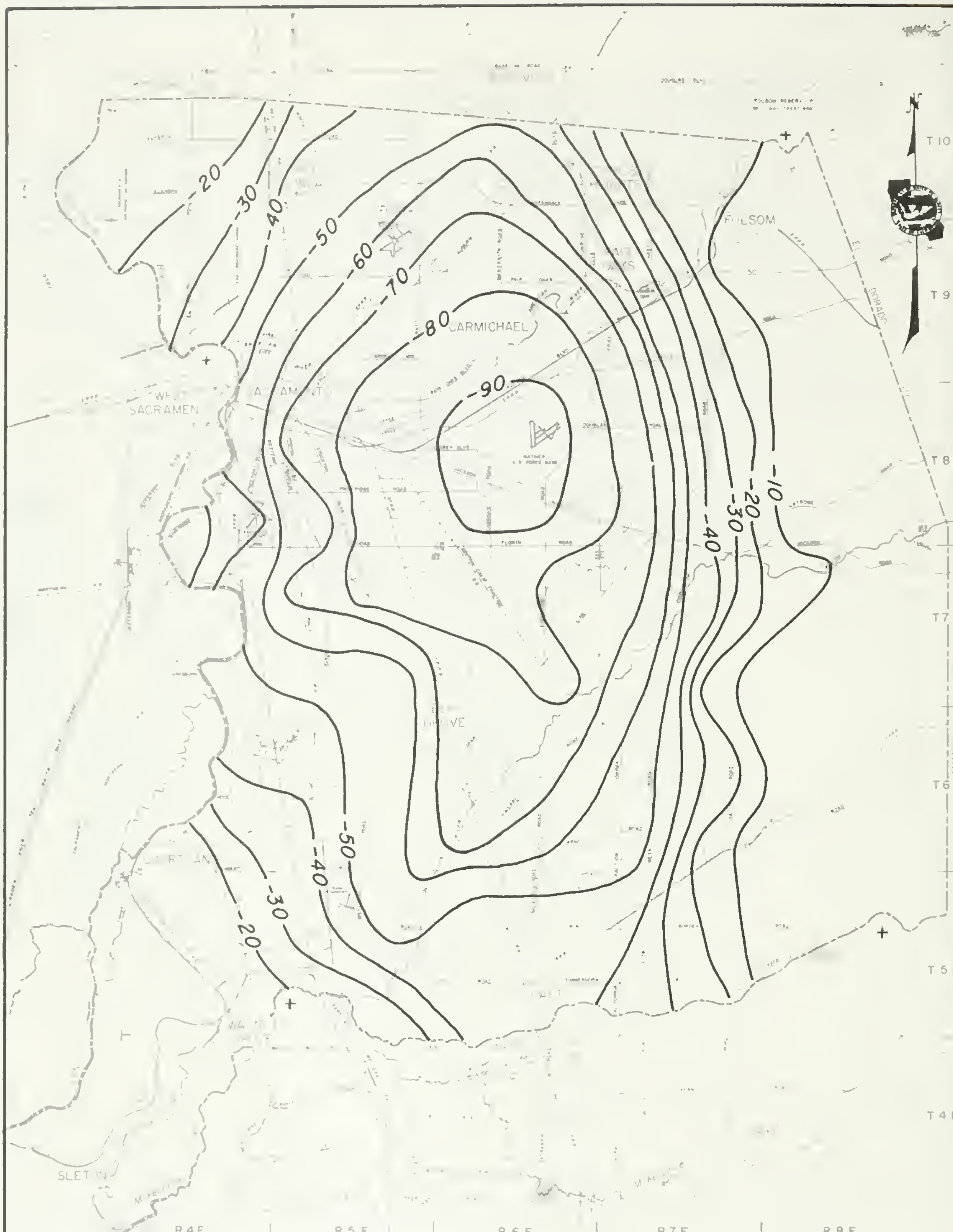


Figure 21. ALTERNATIVE PLAN A
CHANGE IN WATER LEVELS FROM 1970 TO 2020

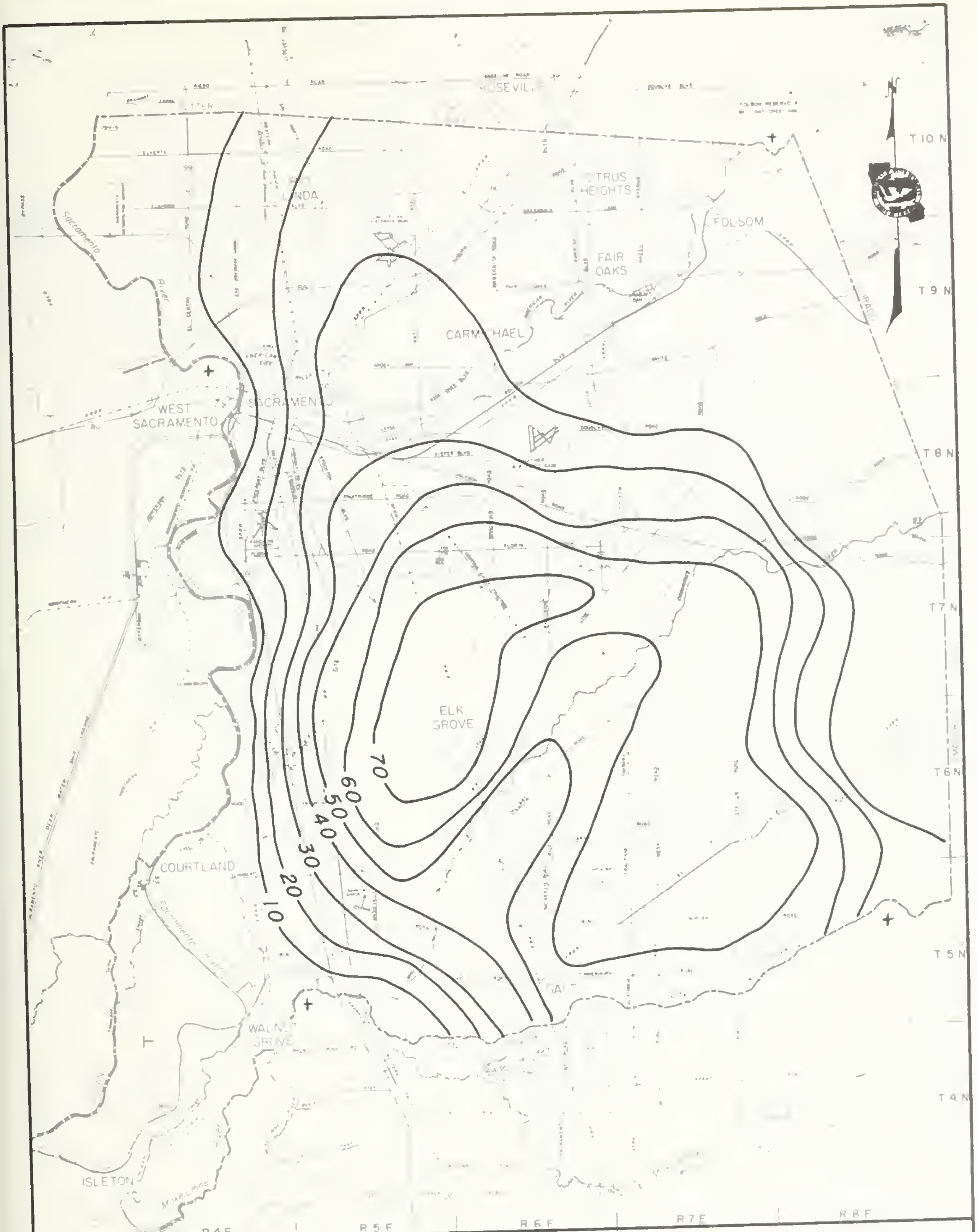


Figure 22. ALTERNATIVE PLAN B
CHANGE IN WATER LEVELS FROM 1970 TO 2020

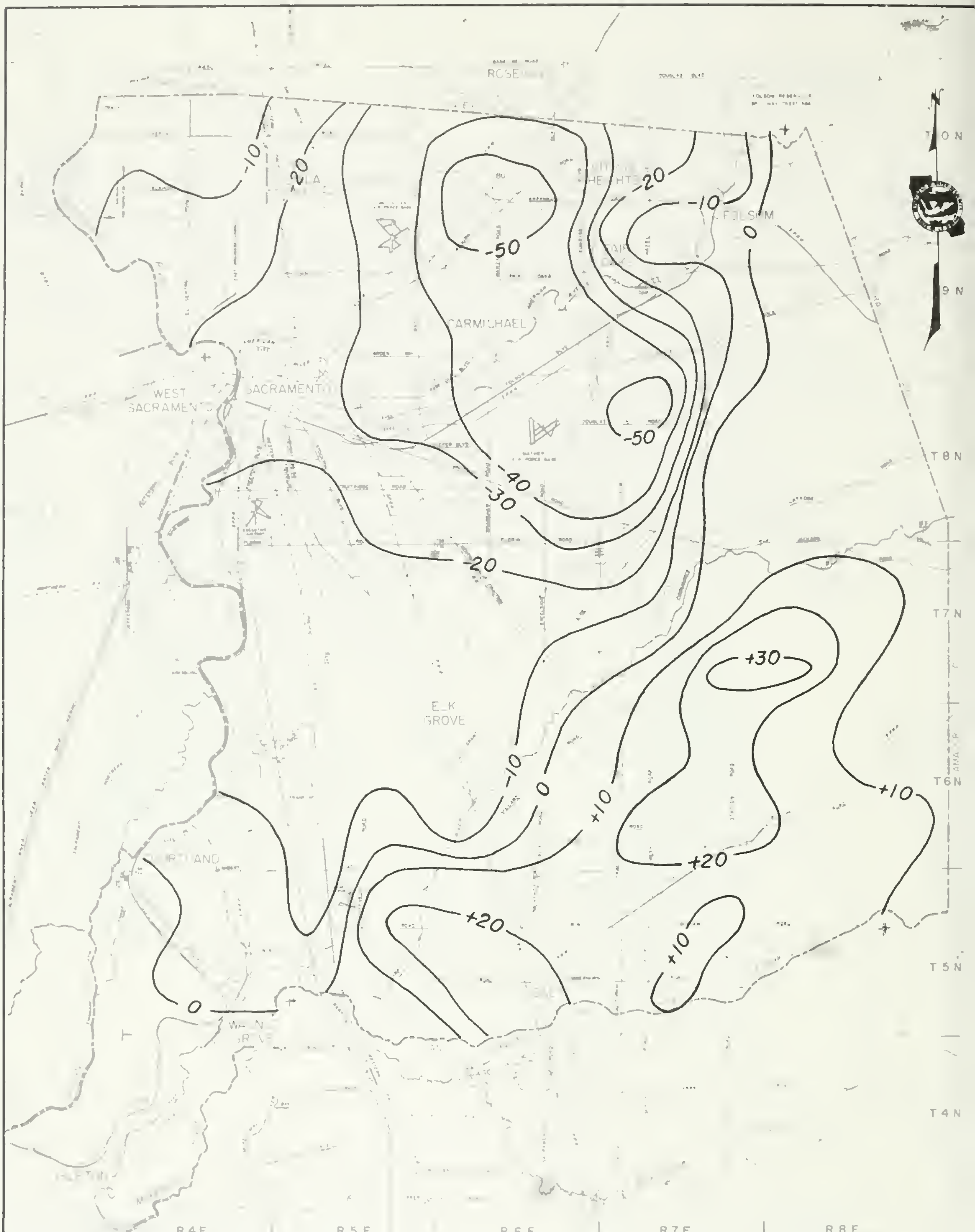


Figure 23. ALTERNATIVE PLAN C
CHANGE IN WATER LEVELS FROM 1970 TO 2020

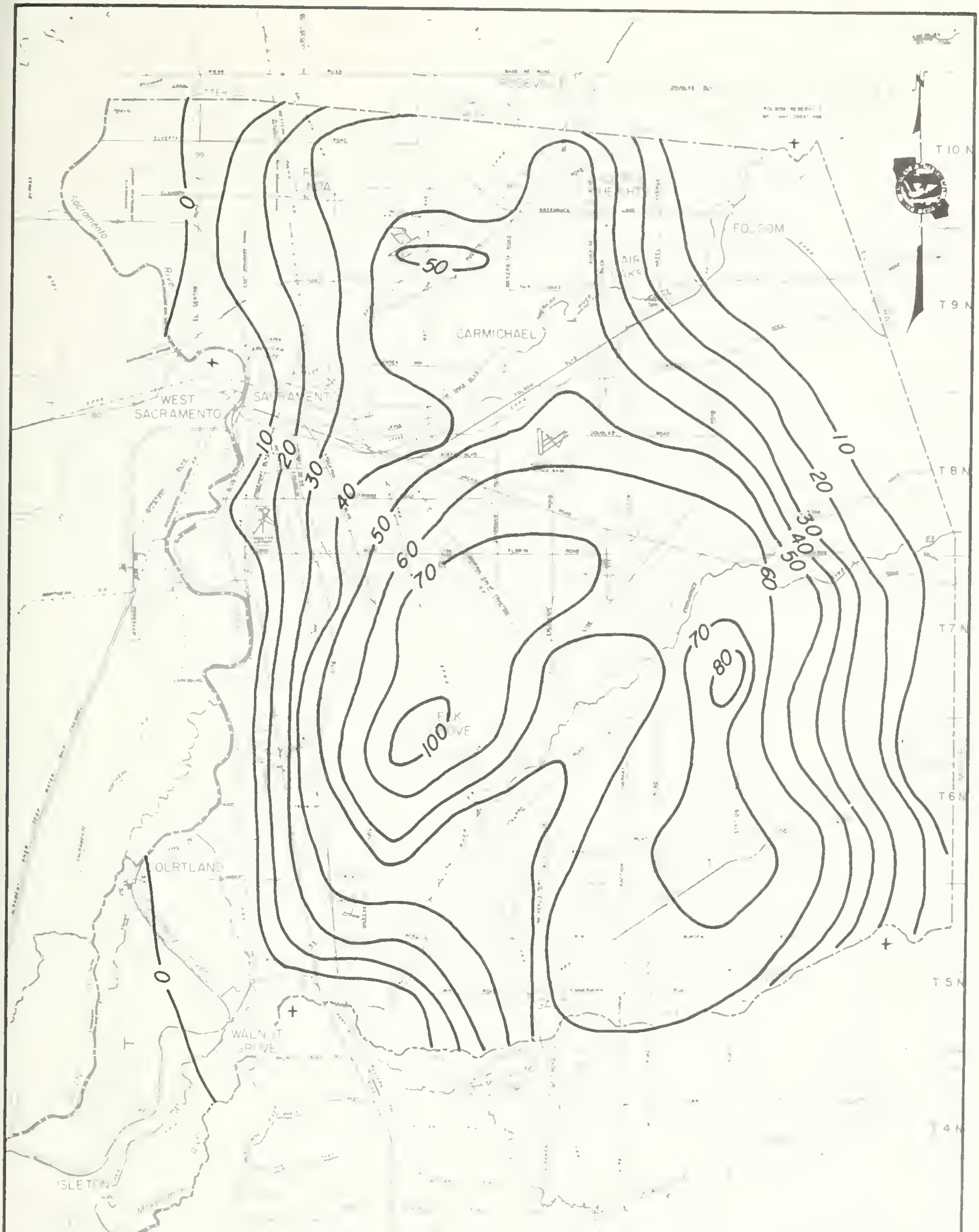


Figure 24. ALTERNATIVE PLAN D
CHANGE IN WATER LEVELS FROM 1970 TO 2020

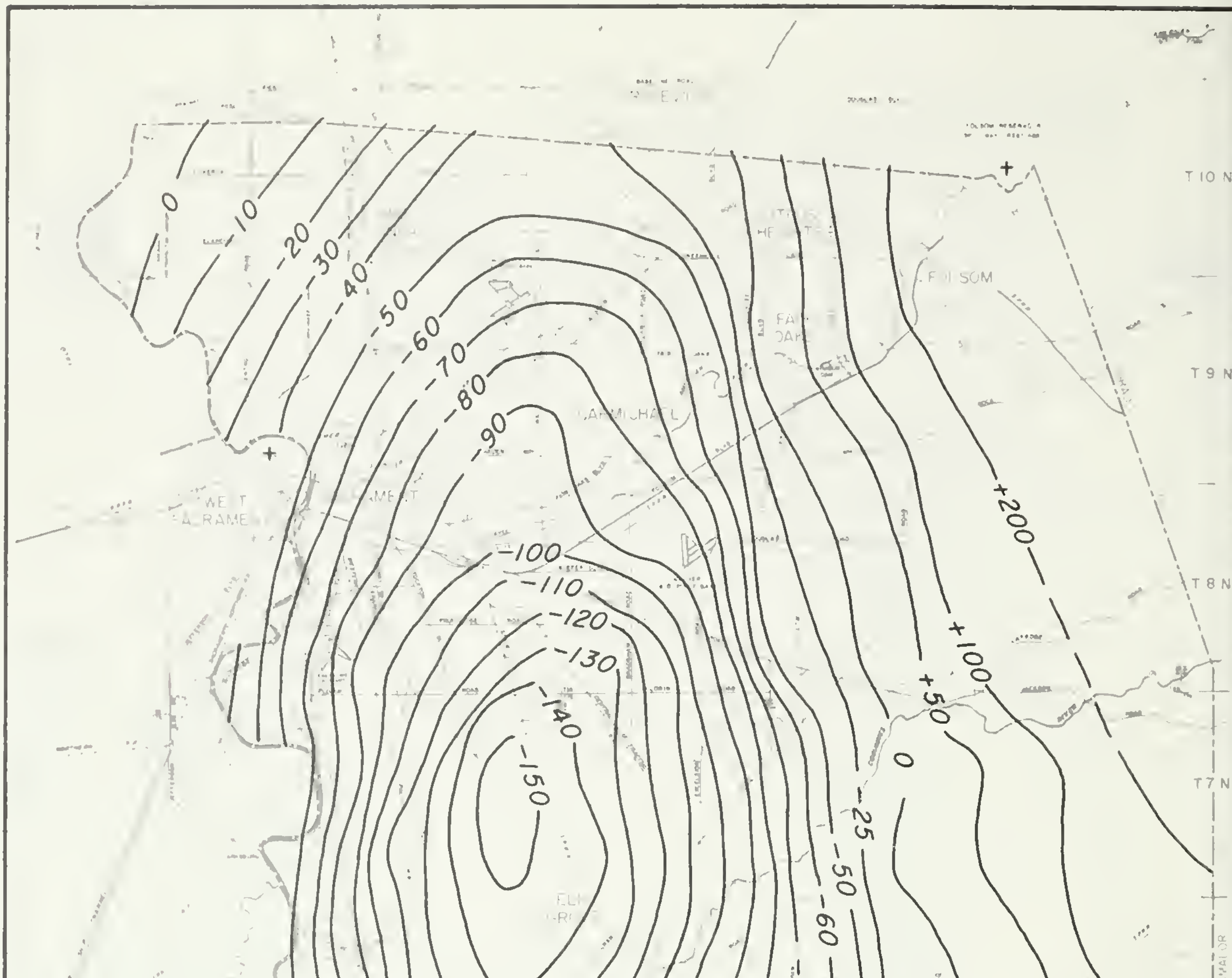


Figure 25. PLAN A
2020 PROJECTED WATER LEVEL ELEVATION

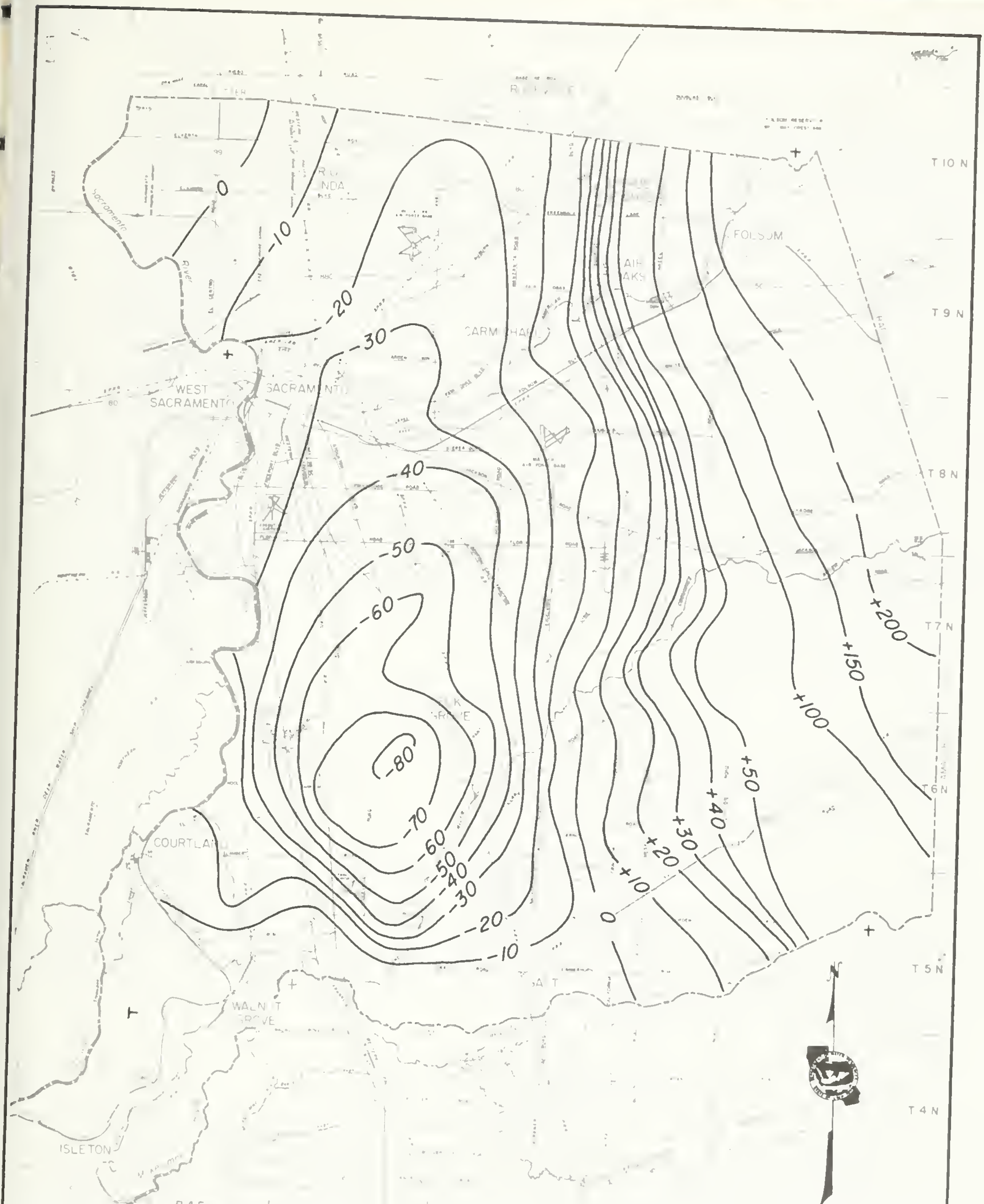


Figure 26. PLAN C
2020 PROJECTED WATER LEVEL ELEVATION

The predicted water levels for all of the plans of operation are shown on Figures 27 and 28 for Nodes 23 and 58, respectively. These two nodes were selected as examples due to their geographic locations. Node 23 is located in the north metropolitan area with Kaiser Hospital situated about in the center of the nodal area. In general, the computed water levels of Node 23 follow the same trend for the same plan as the accumulated change in ground water storage in Figure 19. Surface water and ground water have equal costs for irrigation when the water level is 67 feet below the present pumping level. This is calculated by dividing the difference between the cost of surface water and ground water for irrigation by the cost for increased lift per foot for power and well deepening. For Node 23 this pumping level for agriculture is insignificant because agricultural irrigation is nonexistent in the area. For municipal and industrial water the equal cost level is calculated to be 205 feet below its present level of pumping.

Node 58 is located northwest of Elk Grove, just north of the south pumping depression. The graph shows a slight recovery trend of the water levels from 1970 to about 1975 under all plans, due to the City of Sacramento's conversion to surface water, and after that, under Plans A and E, the water level declined steadily to 2020.

Operational Variables

In each plan only two items were considered to be variable: (1) the amount of water pumped from the ground, and (2) the amount diverted from the surface source.

Cost Considerations

In computing the total cost of each plan, only those costs that vary with the different plans were considered. For this study, those costs were for additional facilities (both for ground water and for surface water) and the costs for surface water. No cost was assigned to a possible change in water quality or to possible subsidence of the land.

Pumping Municipal and Industrial Ground Water

For the cost analysis, 75 HP was chosen as representative of a pump motor on a well. While most new wells are probably equipped with 100 HP motors, many existing wells have motors which are smaller than 75 HP. A $45,000 price for equipment installation was chosen from analysis of records of Sacramento County and data provided by Clendenen (1972). The price includes engineering, pump, motor, electrical equipment, site improvements,

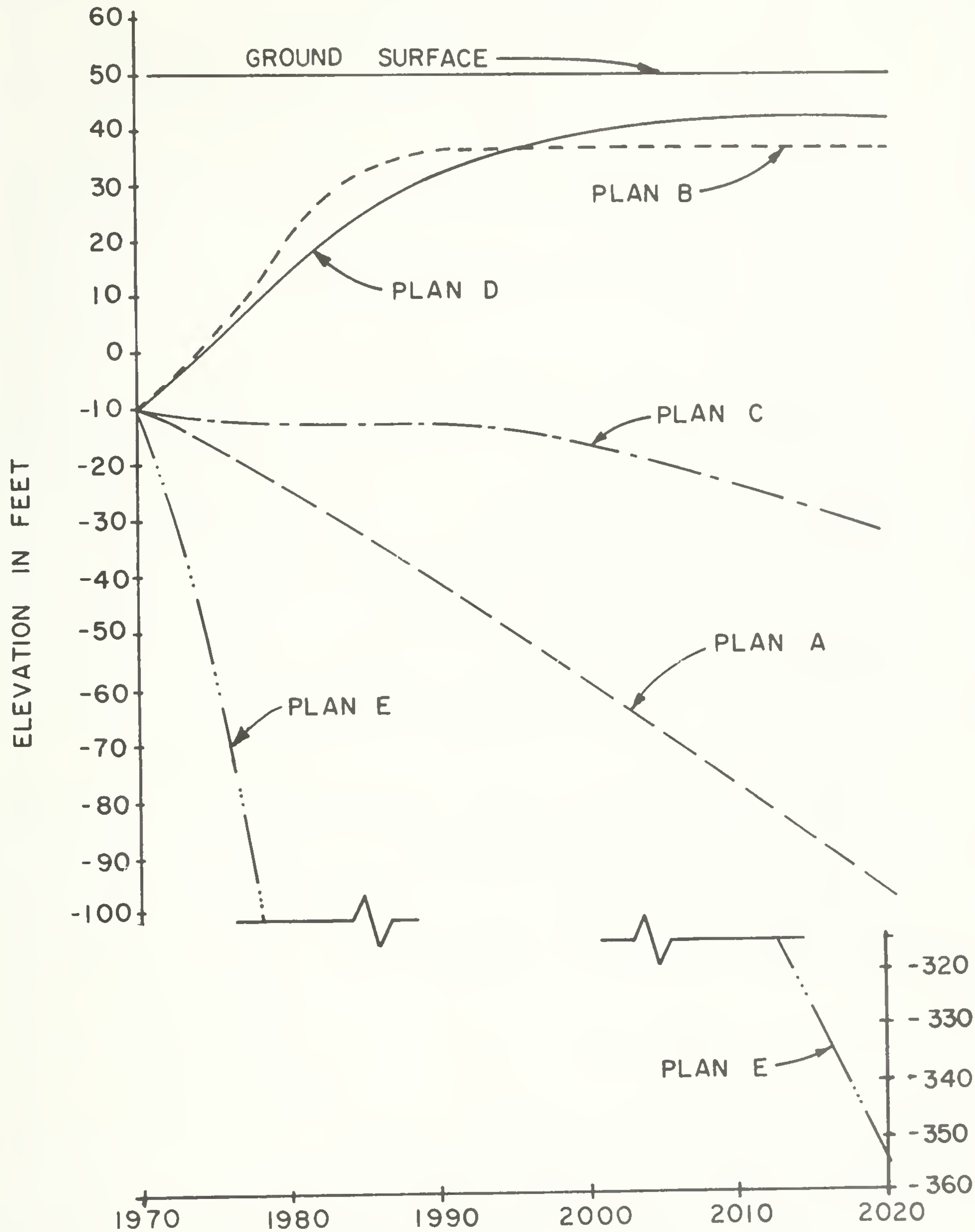


Figure 27. NODE 23 - FUTURE WATER LEVELS UNDER ALTERNATIVE PLANS

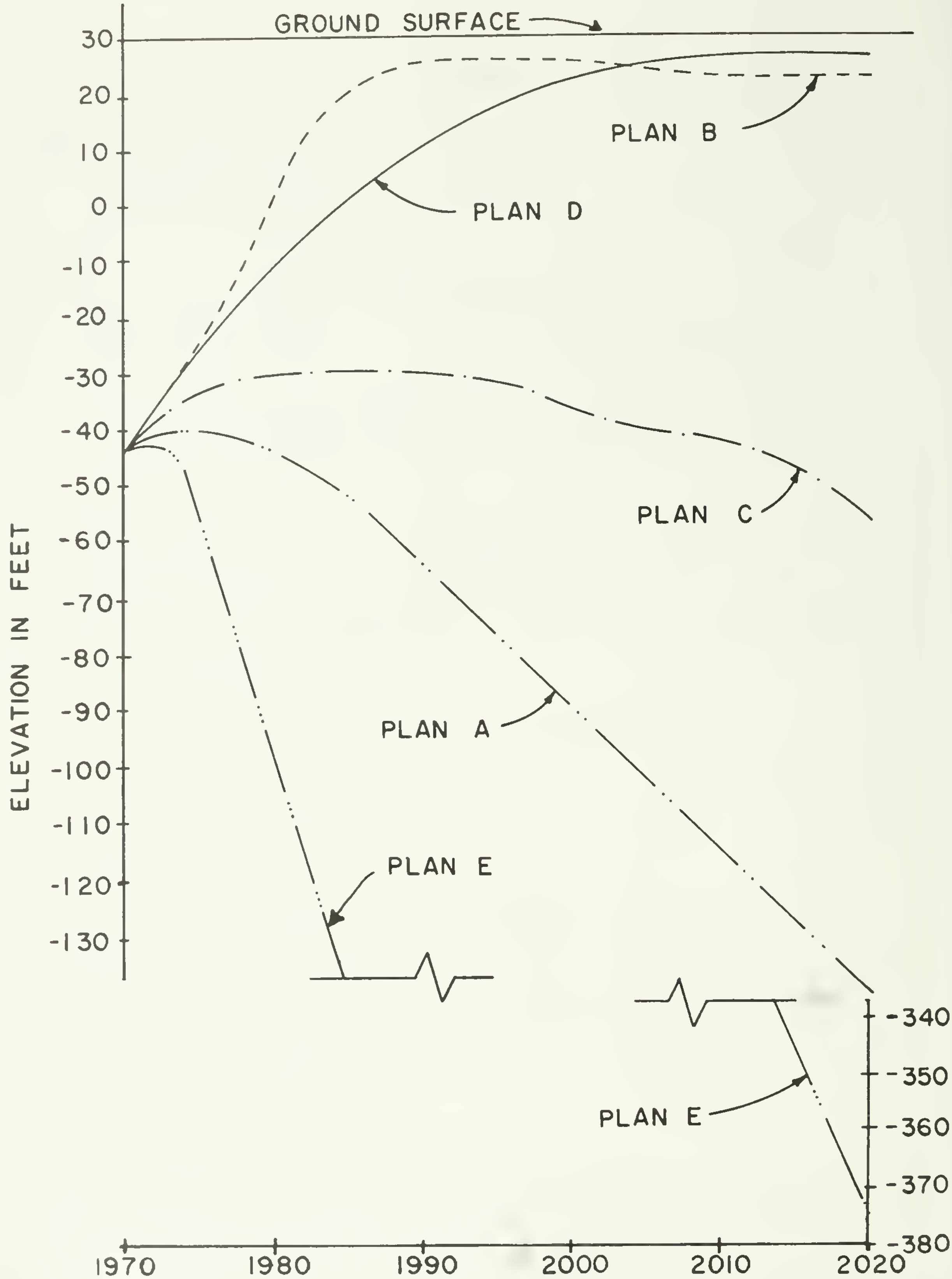


Figure 28. NODE 58 - FUTURE WATER LEVELS UNDER ALTERNATIVE PLANS

right-of-way, and valving for hookup to the distribution system. It also includes cost for some pressure tanks estimated to be needed at 30 percent of the sites.

An annual pumping rate per well of 330 acre-feet was obtained by averaging the rates of Northridge Water District, Rio Linda Water District, Arcade County Water District, Citrus Heights Irrigation District, and Sacramento County Maintenance District well productions. The annual Capital Recovery Cost is $45,000 x 0.07095 = $3,192 (.07095 = Capital Recovery Factor with $i = 0.05$ and $n = 25$ years); $3,192 ÷ 330 = $9.68 per acre-foot per year.

The pump efficiencies of Citrus Heights Irrigation District, Fair Oaks Irrigation District, Fruitridge Vista Water Company, City of Galt, and Arcade County Water District were averaged. The average pump and well efficiency was found to be 61 percent. In order to determine the power cost, the average of 330 acre-feet was broken down on a monthly demand as follows: January, 15 acre-feet; February, March, April, October, November, and December, 20 acre-feet; May and September, 25 acre-feet; and June, July, and August, 45 acre-feet. Using Sacramento Municipal Utility District (SMUD) Rate 47, the average yearly power cost is $5.80 per acre-foot. The 1972-73 power cost of Sacramento County's 16 wells was $6.84 per acre-foot, which is slightly higher. The $5.80 power cost assumed a total pumping head of 240 feet, of which the static lift is 80 feet, drawdown is 20 feet, and pressure head is 140 feet (60 psi).

Well maintenance cost for 14 wells in the Sacramento County system for 1972-73 was $1,889.91 per well, or $5.82 per acre-foot (each well produced 300 ± acre-feet). Clendenen (1969) listed operations and maintenance cost for an average of eight districts at $11 per acre-foot in 1967. Using the ENR cost index, this would increase to $18.70 as of January 1, 1973. The City of Sacramento operating and maintenance costs, including administration, for several years are broken down as follows:

Water Production	52%
Distribution	32%
Water Cost	3%
Administration	13%

In this economic analysis, only variables between ground and surface water are compared. It is assumed that distribution costs through the laterals (12-inch and smaller pipes) and administration costs are the same for both surface and ground water. Therefore, to reduce the eight district average to production cost, deduct 32 percent, which represents the distribution cost on laterals 12 inches and smaller: $18.70 - 32 percent (18.70) = $12.72, less power cost ($5.80) = $6.92 acre-feet per year, which is the average operation and maintenance cost for wells.

Due to possible inaccuracies in extending the ENR cost index, the operation and maintenance cost less power was fixed at \$6.00 per acre-foot per year.

The State Department of Health indicates that its future policy will require chlorination of well water. Chemical, maintenance, and replacement cost for this chlorination treatment is estimated to cost \$2.00 per acre-foot.

The total annual pump cost per acre-foot then becomes:

	\$ 9.68	Capital Recovery (Replacement)
	5.80	Power
	6.00	Maintenance (Well and Pumps Only)
	2.00	Chlorination
	\$ 23.48	TOTAL
USE	\$ 23.50	

The power cost per increased foot of depth is \$5.80 ÷ 240 = 2.4¢ per foot. The overall cost was estimated from the total yearly cost per acre-foot of pumping water: \$23.50 per acre-foot per year ÷ 240 (total head) = 9.79¢ per acre-foot per foot of head, call 9¢ per acre-foot of increased depth.

Pumping Agricultural Ground Water

The 20 HP size for irrigation wells was determined from the following data: The "South County Conservation Plan" by McCreary-Korestsky Engineers, reports that 22 percent of the farms in the Folsom South area are 80 acres, which would require a 20 HP pump. Data from SMUD indicate that the average agricultural well in Sacramento is 20.9 HP. Based on this information, a 20 HP pump was selected as the average size in Sacramento County. The capital costs for well, motor, pump, etc., of this size were found to average \$9,000.

Records from SMUD indicate that average yearly pumping for agricultural wells (excluding rice) is 235 acre-feet per year per well. This would irrigate 85 acres using 2.74 acre-feet per acre, the per-acre rate developed from the ground water study. Land ownership figures in the Folsom South Unit indicate 50 percent of the farms are smaller than 115 acres. Therefore it is assumed that 235 acre-feet per year is the average well production.

Annual power costs were computed from SMUD Rate 63 effective June 29, 1972. An overall efficiency of 54 percent and a total pumping head of 100 feet (drawdown is 20 feet) were used in computing the power cost of \$1.95 per acre-foot. It should be noted that this is considerably lower than the power cost for municipal and industrial pumpage. The difference in pumping head and power rates causes the wide variation in power cost. Annual capital recovery costs are:

$$\$9{,}000 \times 0.07095 = \$638.50$$
$$\$638.50 \div 235 = \$2.72/\text{acre-foot}$$

Annual maintenance costs are assumed to be $1.00 per acre-foot per year ($235 annually). Total annual costs per acre-foot are:

$ 2.72	Capital Recovery
1.95	Power
1.00	Maintenance
$ 5.67	Total Annual Cost per Acre-Foot

Noting that the SMUD records indicate that power costs for irrigation average $2.40 per acre-foot (not $1.95 as computed), Sherman and Sullivan show a $7.59 per acre-foot cost for agricultural pumping. Economists with the Bureau of Reclamation place pumping cost at $6.00 per acre-foot. The $1.95 per acre-foot power charge was increased to $2.28 in order to bring the total pumping cost to $6.00 per acre-foot per year:

$ 2.72	Capital Recovery
2.28	Power
1.00	Maintenance
$ 6.00	Total Annual Cost per Acre-Foot

The increased cost per foot of depth was determined from $6 ÷ 100 of Head = 6¢ per acre-foot for one foot of increased depth of pumping.

Surface Water

In the economic analysis, certain costs for surface water were used in the calculation. These costs are listed in Table 14.

Agricultural Surface Water Supply. Natomas Mutual Water Company pays the U. S. Bureau of Reclamation $2.00 per acre-foot for water diverted from the Sacramento River for the months of June, July, and August. In the other months, Natomas has water rights to the water. The $1.50 charge for water used in our calculation is an average charge for water. For the Folsom South service area, at the present time the Bureau, in contract negotiations with Sacramento County Water Agency, is pricing agricultural water at $6.00 per acre-foot from the Folsom South Canal.

Municipal and Industrial Water Supply. Carmichael Irrigation District pumps water from Ranney Collectors along the American River and the District has water rights to the water.

San Juan Suburban Water District diverts water from Lake Folsom, and has rights to 33,000 acre-feet of water at no cost. They have contracted with the Bureau for an additional 11,200 acre-feet at $6.00 per acre-foot from the same diversion point. They have also contracted with Placer County Water Agency for 25,000 acre-feet at $9.25 per acre-foot. This water is also diverted at the same point in Folsom Dam. For the economic study, $2.50 per acre-foot was used as an average annual cost for water.

Table 14

SURFACE WATER COST USED IN THE ECONOMIC ANALYSIS

Items	Cost per Acre-Foot	Comments
AGRICULTURE		
Natomas Mutual Water Company	$ 1.50 2/	Water rights to some water.
Folsom-South Service Area	6.00	Price not firm as of this date.
(Farmers along river and some streams)	0.00	Water rights.
MUNICIPAL AND INDUSTRIAL		
Carmichael Irrigation District	$ 0.00	Water rights.
San Juan Suburban Water District	2.50 2/	Water rights to 33,000 AF.
City of Sacramento	9.00	Water rights to most water. Pays on a minimum schedule. 1/
City of Folsom	0.00	Water rights.
Folsom-South Service Area	16.00 3/	

1/ City of Sacramento Minimum Schedule

1970	$ 99,000
1980	144,000
1990	198,000
2000	270,000
2010	396,000
2020	603,000

2/ This is the average price paid for water. Total use includes water rights and purchased water.

3/ Price to EBMUD and SMUD is $16.00 per acre-foot.

The City of Sacramento diverts water from the Sacramento River for the Sacramento River Water Treatment Plant, and from the American River for the American River Water Treatment Plant. The City has water rights to divert up to a maximum rate of 225 CFS from the Sacramento River, but not to exceed 81,500 acre-feet per year, and water rights in the American River of 675 CFS. Some of the water from the American River is obtained through an agreement with the Bureau of Reclamation; most of the water is by water rights. The City pays the Bureau at a rate of $9.00 per acre-foot, with an agreed minimum schedule, which is footnoted in Table 14.

The City of Folsom obtains its water from Lake Folsom at no cost, due to prior water rights.

Contract negotiations between Sacramento County Water Agency and the Bureau of Reclamation for Folsom South Canal water for municipal and industrial purposes is priced at $16.00 per acre-foot. This price is not firm at the present time; however, it was used for the economic analysis.

Producing and Distributing Municipal and Industrial Surface Water

The costs of producing and distributing municipal and industrial surface water were computed from data from the San Juan Suburban Water District and the City of Sacramento.

The 1972 "Project Report, Domestic Water Supply System" for the San Juan Suburban Water District and a subsequent report on the initial study by CH_2M-Hill and Associates have tables indicating costs to Citrus Heights Irrigation District, Fair Oaks Irrigation District, and Orangevale Mutual Water Company. By averaging the cost to each district and assuming no federal grants, the average annual costs are $29.20 per acre-foot per year. The $29.20 includes raw water cost, which averages with water rights at $2.50 per acre-foot. Note also that this cost does not include the OM&R cost on the existing distribution system and does not include cost for plant right-of-way. The average annual cost for water production is $23.71 per acre-foot (not including plant site right-of-way) for a 100 mgd plant.

Data received from the City of Sacramento list total annual production cost at $28.85 per acre-foot for a 75 mgd plant and distribution cost of $14.25. Distribution costs are the costs associated with the mains, booster stations, etc., not required in a water system depending on wells. The $28.85 includes right-of-way cost and assumes the plant is at full capacity.

Comparing the $23.71 figure from San Juan Suburban Irrigation District (which does not include right-of-way) and the $28.85 figure from the City of Sacramento, the difference can probably be attributed to the fact that San Juan has (1) somewhat lower pumping costs, due to the strategic location of their plant, and (2) no capital recovery cost for right-of-way. For the purposes of this study it will be assumed that an average production price will be $25.75. Total costs are $25.75 + $14.25 (distribution cost above that required in a well system) = $40.00 per acre-foot per year. This represents the total annual cost of treating and distributing municipal and industrial surface water.

Distributing Agricultural Surface Water

The cost of distributing agricultural surface water was determined from records of the Natomas Mutual Water Company; the USBR Folsom South report; engineering studies by John S. Longwell, Consulting Engineer, prepared for Sacramento County; and reports for Galt Irrigation District prepared by Sherman and Sullivan.

The USBR Folsom South report shows an operation, maintenance, and replacement (OM&R) cost (updated by ENR cost index) of $5.47 per acre-foot per year. The Natomas Mutual Water Company charges maintenance costs of $2.75 per acre per year, which averages $0.46 per acre-foot per year. Operation cost averages $1.66 per acre-foot per year. Replacement costs (estimated from Folsom South) are $0.25 per acre-foot per year. The total for Natomas is $2.37 per acre-foot per year. The Longwell report (updated) lists OM&R cost at $3.06 per acre-foot per year. The Sherman and Sullivan report lists distribution system repayment cost at $9.39 and operation and maintenance at $4.00. This combined cost of $13.39 divided by 3.6 acre-feet (average water application per acre) gives OM&R cost of $3.71 per acre-foot per year.

The average of these costs for OM&R is $3.65 per acre-foot per year, and the price used for OM&R cost for agricultural water was established at $4.00 per acre-foot for this study.

Water Quality Variables

Although the quality for surface and ground waters differs, the differences are small and the quality of both sources is good. Economic effects associated with these differences are considered by this study to be insignificant. Therefore, no attempt was made to assign a cost to the difference in water quality.

Economic Evaluation

The total of all these costs enumerated above from 1970 through 2020 constituted the cost of water service. These costs may occur at different times for each plan of operation. Therefore, the economic effect of incurring the same expenditure at different times would vary with the plan. To be a viable economic comparison of all alternatives, this time difference must be considered, and to do so, all costs must be converted to a common denominator, called "present worth".

Present Worth

Present worth of the variable cost of water service under each plan of operation may be considered as that amount of money which must be deposited today in an account earning 5 percent interest to meet future costs associated with providing water service. Thus, a comparison of present worth of the four plans would provide a comparative measure of the extent of costs.

Table 15 shows the present worth of the future costs for the four operational plans. Line 5 lists the total present worth of each plan, which varied from $291 million to $353 million. With the present energy crisis, it may be possible for the power charges to double, so an analysis was made to determine what economic effects doubling power charge had. Line 6 lists the result of that analysis with no change in the relative position of the plans. With the present power charges or doubling the power charges, Plan A (which is the existing operational system) is the most economical. However, in 2020, each of the other plans will have from 1.2 million to 3.3 million acre-feet more ground water in storage than will Plan A.

Ground water in storage has no economic value until it is put to beneficial use. The economic value of the ground water in storage is evaluated by extending the period of analysis out to 2070. The operational scheme will consist of safe yield basin operation for Plan A, and Plans B, C, and D will use their ground water in storage of 3,070,000 acre-feet, 1,157,000 acre-feet, and 3,258,000 acre-feet, respectively, such that in 1970, the ground water in storage will be the same for all plans.

It was assumed that for the 2020 to 2070 analysis, the water requirement, price of water, and total benefits will remain constant between different plans. Table 15 lists the present worth of variable cost for the period of analysis from 2020 to 2070 on Line 8. The values of use of ground water in storage per acre-foot were $0.65, $1.38, and $0.46, respectively, for Plans B, C, and D, and were derived by dividing the difference in present values by the ground water in storage. Based on the period of analysis, 1970 to 2070, it would be very difficult to decide on a plan in view of the assumptions and approximations made in this study. Thus, political, legal, and organizational factors would probably dictate the final selection of the plan of water resources management by the local implementing agencies. For example, Plan B value of $0.65 per acre-foot of storage was derived by dividing $2,000,000 ($36,300,000 - $34,300,000) by 3,070,000 acre-feet (+1,791,000 + 1,279,000).

TABLE 15

PRESENT WORTH OF FUTURE COSTS FOR ALTERNATIVE PLANS
(In Thousands of Dollars)

Item	Plan A	Plan B	Plan C	Plan D	Plan E
1. Agricultural Surface Water Cost	38,070	56,660	42,430	48,040	0
2. Agricultural Ground Water Pumping Cost	26,820	12,860	24,290	19,760	115,100
3. Municipal & Industrial Surface Water Cost	117,000	157,370	138,200	164,740	0
4. Municipal & Industrial Ground Water Pumping Cost	109,110	80,010	94,680	77,260	237,700
5. Present Worth of Variable Cost (1970 to 2020)	290,900	306,900	299,600	309,800	352,800
6. Present Worth of Variable Cost Using Double Power Charges (1970 to 2020)	333,900	339,500	339,200	344,700	456,400
7. Change in Storage (in 1,000 acre-feet)	-1,791	+1,279	-634	+1,467	-9,643
8. Present Worth of Variable Cost (2020 to 2070)	36,300	34,300 1/	34,700 2/	34,800 3/	--
9. Present Worth of Variable Cost (1970 to 2070)	364,300	378,100	371,300	383,800	--

1/ Ground water storage is $0.65 per acre-foot.
2/ Ground water storage is $1.38 per acre-foot.
3/ Ground water storage is $0.46 per acre-foot.

Values are calculated by dividing the difference in the present worth of each plan by the difference of the ground water in storage of each plan.

CHAPTER V. FINANCIAL AND INSTITUTIONAL CONSIDERATIONS

The operational study was conducted under the presumption that all legal obstacles would be overcome and that the necessary management organization would be made available to implement any physical plan. For this study, in the previous chapters only the operational and economic factors were considered. Other factors which will be of importance to those local agencies having decision-making authority are discussed in the following paragraphs.

Financial Considerations

This section considers financial items not previously discussed that may affect the total cost of water supply.

Fire Protection

Fire protection is provided by the local fire protection district. This district, together with the water distribution system, is graded by the Insurance Services Office of California into Fire Protection Classifications to determine the fire insurance rates.

Fire protection classification is determined by an engineering study and appraisal using a grading program developed by the Insurance Services Office, Municipal Survey Service, New York. The classification is not a measure of the efficiency of local fire protection services, but a device for anticipating the probability of large fires or conflagrations in the area. The grading is on a deficiency point basis, with the number of points determining a jurisdiction's classification. These classes range from Class 1 (best possible) to Class 10 (no fire protection).

Thirty-nine percent of the potential deficiency points are attributable to inadequacies in water systems. These deficiencies are the results of inadequate water quantity or pressure, undersized mains, inadequately sized or spaced fire hydrants, adequacy of valving, management factors, and other features of the water system which affect its fire protection capabilities.

Higher fire protection classes are characteristic of the unincorporated area of the County, as compared with the City of Sacramento. This is amply illustrated by comparing the fire protection class of the City, which is 3, and the average of the remaining metropolitan area, which is 5. This average figure was determined from the following fire protection districts: Arcade, Arden, Citrus Heights, Fair Oaks, Fruitridge, North Highlands, Pacific, Rancho Cordova, and Rio Linda.

The average deficiency points assigned to water supply is 561 in the metropolitan area of the County, as compared to 238 for the City of Sacramento. This difference is primarily due to the different criteria or controls applicable to the development of water systems in the two areas in the period of rapid development following World War II. While developers constructed much of the new water facilities in both the City and unincorporated areas, the standards regarding pipe sizing, valving, and fire hydrants were more rigid in the city area than in the unincorporated areas.

The increase in deficiency points due to design criteria results in a 0.65 class increase in fire protection. This class increase results in a yearly rate increase of approximately $2.00 on the average $20,000 home, as computed from the following table. (Computed for $20,000 owner-occupied frame dwelling with $10,000 for contents.)

ONE YEAR PREPAID FIRE INSURANCE PREMIUM

Protection Class	Premium Per Year
2	$ 41.76
3	45.41
4	48.24
5	51.57
6	58.22
7	68.01
8	78.22
9	119.64

Source: Insurance Services Office of California, Habitational Tariffs, District II, Class D Dwelling Buildings and Contents, corrected to May 1, 1971.

This additional cost of fire protection insurance is typically paid by homeowners whose water supply is from agencies in the County other than the City of Sacramento.

Staging of Construction

A water supply system utilizing ground water is better adapted to stage construction because of lower capital outlay. A 1,000 gallon per minute (gpm) capacity well is approximately equal to a 1 million gallon per day (MGD) capacity for a surface water treatment plant. The construction cost of the 1,000 gpm well is about $50,000, and for the 1 MGD capacity is about $200,000, or about a four to one ratio in capital outlay.

However, surface water treatment plants are not economically constructed in modules of 1 MGD. Assuming the economical module is about 5 MGD, the capital outlay ratio is 20:1 ($1 million versus $50,000) during the initial 1,000 gpm demand. As the water demand increases to 5,000 gpm, the capital outlay ratio drops back to 4:1. This gives the ground water system an advantage over the surface water system as far as capital outlay is concerned in staging of construction in meeting the growing water demand.

Spillover of Benefits

It can be demonstrated in the model that a purveyor using ground water benefits when surrounding purveyors elect to use surface water. This results in a rising, or at least a slower falling, of water levels because less water is pumped from the ground and additional water is imported and percolated through irrigation to the basin.

The economic analysis in the preceding chapter takes into consideration the additional cost of lifting the ground water to the surface as water levels fall under the various alternative plans. These costs are included in the overall economic considerations. However, not considered in these costs are the benefits to the ground water users resulting from the current 54 percent use of surface water.

In the study area each 100-foot drop in water surface costs an additional $9 per acre-foot for pumping lift. For Node 23, shown on Figure 27, the pumping cost differential between Plan A and Plan C is 57 feet in 2020, which is an additional $5.19 per acre-foot pumping cost. Model studies indicate that the difference between Plan C and a plan using only ground water would be approximately 300 feet in 2020. This would amount to a cost differential of $27 per acre-foot additional pump lift.

A similar comparison can be made for the agricultural area of the County, as shown on Figure 28. The additional cost of lifting agricultural water is $6 per acre-foot per 100-foot lift, and the lift differential between Plans A and C is 48 feet in 2020. The cost difference for lifting is $2.88, or 40 percent of the current agricultural pumping rate. The difference between Plans A and E is $18 per acre-foot. This large increase in cost could have serious consequences on agriculture in the County.

There is, then, a spillover of economic benefits to ground water users when others use surface water. The amount of the advantage depends upon the location and the amount of surface water used.

Protection of Water Sources

A major difference between the alternative plans presented is the amount of present and future surface water sources that will be put to use. The approximate entitlements and contracts amount of 859,200 acre-feet shown on Table 11 is subject to the State Water Code, which generally provides that rights to water are contingent upon that water being put to beneficial use. Possible contracts with the U. S. Bureau of Reclamation from Folsom South Canal total 400,000 acre-feet. The status of water rights is shown on Table 16. It is obvious from examining Table 11 that the 1969 diversions of 435,760 acre-feet are less than half of the present and future surface water sources.

The firming up of a water right requires that the water be put to beneficial use. The use of surface water to replenish ground water previously removed from storage might be considered a beneficial use, but the use of surface water for the sole purpose of protecting some form of right would not be considered a beneficial use.

Increases for future growth are permitted, but growth patterns must be reasonably projected. Growth projections presented in this study indicate that some districts and agencies will have demands that will be less than the total amount of their present surface water sources in the foreseeable future (2020). If this situation continues, it is possible that maximum diversions shown in water rights applications could be reduced by the State Water Resources Control Board.

Although such action might be delayed or prevented for some of the water purveyors by local action, the best protection possible for the water rights of the water purveyors of Sacramento County is joint agreement of what future water demands will be and how they will be met.

The organizations which may not be able to put all of their surface water sources to use are: City of Sacramento, Carmichael Irrigation District, Natomas Mutual Water Company (lost as farmland becomes urbanized), and Sacramento County Water Agency. Realistic needs for the total amounts available from surface water sources are under review by the Department of Water Resources as part of its current review of the California Water Plan.

Table 14 indicates the average cost of purchased water used in the economic analysis. It is evident from this table that a wide range of prices are paid or will be paid for water. This wide range in water cost is reflective of the early procurement of water sources by those agencies who enjoy the less expensive water.

The economic impact of changing water prices (assuming that the least expensive water source would be put to use first and the more expensive source would be subject to reduction) was not investigated in this report because of the many possible combinations for sharing excess entitlements that exist. It is doubtful that a significant change in the economic analysis of the various alternative plans would occur because the main difference in present worth values shown in Table 15 results from the cost of treating surface water.

Table 16

SUMMARY OF WATER RIGHTS

	Application Number	Date of Application	Status of Application	Diversion (in CFS)	Source of Water
City of Sacramento	1,743	3/30/20	Permit	225	Sacramento
City of Sacramento	12,140	10/29/47	Permit	500	American 1/
City of Sacramento	16,060	9/22/54	Permit	175	American
City of Folsom					American
San Juan Suburban W.D.	5,830	2/11/28	License	15	American 2/
Carmichael I.D.	138	9/18/15	License	15	American
Carmichael I.D.	4,743	8/22/25	License	10	American
Carmichael I.D.	12,367	3/1/48	Permit	25	American
Natomas Mutual	534	12/13/16	License	42	Sacramento 3/
Natomas Mutual	1,056	8/22/18	License	38	Sacramento
Natomas Mutual	1,203	3/5/19	License	160	Sacramento
Natomas Mutual	1,413	8/27/19	License	120	Sacramento
Natomas Mutual	15,572	10/8/53	Permit	132	Sacramento
SMUD			USBR Contract		American 4/
Sacramento County W.A.			Proposed USBR Contract		American
Galt I.D.			Proposed USBR Contract		American
Other Diversions for Irrigation			Combination License, Permits & Riparian Rights		Sacramento & American 5/

1/ Includes Arcade and Del Paso Manor Water Districts' rights and contractual rights.
2/ Includes other water purveyors in San Juan District and contractual rights.
3/ Includes contractual rights for irrigation only.
4/ All water to be used at SMUD nuclear plant.
5/ Includes Omochumnes-Hartnell and Rancho Murietta, who divert from Cosumnes River.

Availability of Future Water Supplies

The availability or nonavailability of future water supplies is related to water rights and to funding of water projects, and will be of considerable importance to the local agencies in the selection of an alternative plan. Workshops held recently by the Department of Water Resources preliminary to its publishing Bulletin 160-74, "Water for California", indicated a need for additional water development within the State. California's rapid population increases of the early 1960's have leveled off, but additional demands have been made on the water supply. These statewide added demands include: water for fish, wildlife, and recreation enhancement on a scale not previously envisioned; nuclear plant cooling water needed for energy generation; and an ever-increasing demand for irrigation water to supply the world's growing need for food. All of these demands have at least an indirect effect on Sacramento County's water resources.

The only remaining large source of surface water within California is the North Coast. Development of these supplies will be expensive because of the location and the greater amount of environmental protection now required of water development projects. Development of increased water supply through use of reclaimed waste water, desalted water, and other means will also be expensive. The rising cost of water development and environmental consideration will require continuing review of unit water demands and may result in the discontinuance of noneconomic uses for water except where necessary for the general benefit of the environment.

The availability of future additional water is an intangible item, and is not included in the economic analysis for the alternative plans; nevertheless, it is an important factor which must be considered by the local agencies in the selection of an operational plan.

Quality Considerations

In comparing operational plans, no economic advantage was assigned to either surface or ground water supplies on the basis of water quality because there appears little basis at the present levels of hardness of the surface and ground water supplies to assign any economic advantage to either source of supply.

Both sources of water are abundant and excellent. Both are acceptable for most beneficial uses. The most varied quality requirements of water are found for industrial uses, and for the most exacting water quality needs, those users specially treat the water themselves. For the homeowners, if the majority of customers served well water desire soft water, a central softening plant could be constructed or surface and ground water could be mixed at a central plant.

Surface waters in the Sacramento area generally are softer than the ground waters. The City of Sacramento surface water supply has a hardness of approximately 40 mg/l as $CaCO_3$ as compared to consensus rated ground water hardness in the metropolitan area of 105 mg/l (average based on 993 samples). Many homeowners served by well water have water softeners, indicating that consumers generally prefer the softer water, as it lathers better with soap, eliminates or reduces bathtub rings, and results in savings in soap consumption. However, due to the wide use of detergent cleaning compounds, which are little affected by hardness, the economics of water softening are limited. Soft waters are generally considered corrosive, with the corrosive characteristics of a water depending on many factors. Hard waters may also require "balancing" to control corrosion. Technology is available for reducing corrosion to an acceptable minimum.

With the lowering of the water table, ground water gradients will increase toward the pumping depressions. This would enhance the movement of shallow, poor quality water, such as that around the Metropolitan Airport toward the Town and Country area pumping hole. As the water table is lowered, the quality of the water will be lower; for example, TDS may increase.

Institutional Considerations

Existing Institutions

The water purveyors shown on Table 9 are divisible into three institutional categories: private or mutual companies, dependent districts, and independent political subdivisions. Private or mutual companies are a part of the private enterprise system. They are not subject to local control but are subject to the rules and regulations of the State Public Utilities Commission. Taxes, special assessments, ground water extraction charges, or pump taxes can be levied by the County on these private companies. There is also provision in the existing codes for annexing private companies to cities. Inclusion of these companies on anything other than a volunteer basis in overall basin management planning will require intricate studies and negotiations, and perhaps additional state legislation.

Seven of the 21 purveyors who serve over 200 connections each are in the category of private or mutual companies. These are Citizens Utilities, Arvin Water Company, Orangevale Mutual, Arden Water Service, Cordova Water Service, Fruitridge Vista, and Elk Grove Waterworks. In addition, the Natomas Mutual Water Company, a private company, delivers 90,000 acre-feet of agricultural water each year to its service area.

Dependent districts are those operated by Sacramento County and are governed by the Board of Supervisors. There is only one district which has over 200 connections in this category -- the Arden Park Vista Water Maintenance District.

Eleven purveyors who serve over 200 connections each are independent districts or political units. They are organized under four major general water district acts. Independent districts are publicly owned and operated, governed by elected Boards of Directors. The approval of the County Board of Supervisors is usually necessary to form the districts; however, once formed they are independent special districts, subject to the state laws under which they were organized and their own governing boards.

Citrus Heights, Fair Oaks, Carmichael, El Dorado, and Galt are formed under the provisions of the County Irrigation District Act. All except Galt provide domestic water service to their respective areas. Galt was formed to contract for Bureau of Reclamation water from the Folsom South Canal, but maintains no facilities or provides no services at the present time.

The San Juan Suburban Water District is organized under the provisions of the Community Services District Act. This law allows for a variety of services, including water, sewer, parks and recreation, fire, and police protection. However, at the present time, the District provides only water to its service area.

Arcade, Northridge Park, Florin, Rio Linda, and Del Paso Manor are organized under the County Water District Act.

Clay and Omochumnes-Hartnell are organized under the California Water District Act. However, they provide only irrigation water to their respective service areas. Clay Water District was formed to contract for Bureau of Reclamation water from the Folsom South Canal, but maintains no facilities or provides no service at present.

In addition to the above-mentioned purveyors, there are three incorporated cities -- Sacramento, Folsom, and Galt -- which supply water in Sacramento County.

The Sacramento County Water Agency is a specific act district whose boundaries include all of Sacramento County. Specific act districts may be distinguished from the previously mentioned general act districts by their method of formation. General act districts are formed by procedures set forth in the existing codes, while specific act districts are created through a special act of the state legislature.

The Sacramento County Water Agency was initially formed to contract for Bureau of Reclamation water, but does not deliver water at present. The act creating this agency was amended in 1963 to include storm drainage and flood control responsibilities.

Joint Powers

One method of dealing with the institutional problems inherent in the many organizations involved in water supply is through joint powers agreements between the various agencies. Joint powers agreements usually assume that the entities involved have equal powers and mutually benefit from the procedure overtaken in the joint powers agreement. As previously noted, the determination of who benefits and to what extent will be difficult to determine in the case of ground water versus surface water supplies.

County Water Agencies and Flood Control and Water Conservation Districts

In other areas of the State the cost sharing of benefits derived from the use of the more expensive surface water is handled through a countywide water authority, known as a county water agency or flood control and water conservation district.

The Santa Clara Valley Water District, organized as Santa Clara County Flood Control and Water Conservation District, is an example. They utilize a pump tax to pay the cost of importing surface supplies and recharging the ground water basin.

County water agencies and flood control and water conservation districts are specific acts of the state legislature; therefore, each is somewhat unique. Some have the Board of Supervisors of the county as their sole governing board. Sacramento, Contra Costa, and El Dorado Counties are examples of this form of water agency. Alpine and Sutter Counties have appointed Advisory Boards consisting of member agencies to assist the county Board of Supervisors, who act as the water agency governing board. The Kern County Water Agency is governed by a separate Board of Directors elected by district. The Shasta County Water Agency is governed by the County Board of Supervisors and the Boards of Trustees of the various zones of the agencies. The structures of existing agencies range from complete control by the county supervisors through control with advisory boards and shared control with other elected directors to independent elected directors. There are 13 county water agencies and 21 county flood control and water conservation districts in the State.

County Water Districts

There are two county water districts which are specific act districts rather than general act districts. These are Orange County Water District and Alameda County Water District. They are governed by elected Boards of Directors. Orange County Water District was organized in 1933 to store water in underground basins and to improve and protect the quality of the ground water supplies. These were in addition to the usual purposes of a water supply district. Special equity assessments are used to equalize ground water pumping.

A basic pumping rate is established. When a purveyor exceeds his assigned pumping rate, an equity assessment is levied to assist in payments of the extra imported water that another purveyor in the district must purchase in order to maintain the desired balance between surface and ground water.

Metropolitan Water Districts

These districts can be formed under existing state water law, hence are general district acts, as are irrigation and community service districts. Their territory may include two or more "public agencies" (city, municipal water district, municipal utility district, public utility district, county water district, or county water authority). These need not be contiguous. They are governed by a Board of Directors appointed by the chief executive officers of constituent "public agencies" with consent of their governing bodies. The votes are based on assessed valuation in each agency. The Metropolitan Water District of Los Angeles is an example of this type of district, and is the only district so organized in the State.

County Water Authorities

County water authorities are to be distinguished from county water districts. They are formed through a general district act and are similar to metropolitan water districts in their formation, territory, and governing boards. The San Diego County Water Authority is the only one of this type in the State.

Municipal Utility Districts

This form of general district law is used to provide "public agencies" with all types of utilities: light, water, power, heat, etc. Its territory is similar to a metropolitan water district, encompassing any public agency. It is governed by five directors elected at large, but representing a ward. Examples of this type of district are: East Bay Municipal Utility District, which primarily supplies water and sewer service; and Sacramento Municipal Utility District, which furnishes power only. There are five municipal utility districts in the State.

Water Replenishment or Storage Districts

These are two separate general act type districts, but have similar powers and organization procedures. The territory can include incorporated and unincorporated land, generally restricted to the watershed of the stream from which the water supply is taken. They are formed by petitioning the Board of Supervisors of the county in which the greater portion of the territory is situated.

The governing body consists of 3, 5, 7, 9, or 11 directors, depending upon the number of divisions and the particular district which is organized. The taxing limitation for these districts is, generally speaking, more restrictive than other general act type districts. There are eight water storage districts and one water replenishment district in California.

There are several other general act districts which provide water to more than one other "public agency". For example, Community Services Districts (San Juan Suburban is this type). However, those mentioned are the more common methods of areawide organization used in California to organize, develop, conserve, and supply water.

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